WHITE PAPER

Increase inspection performance through 360° in-line surface inspection.

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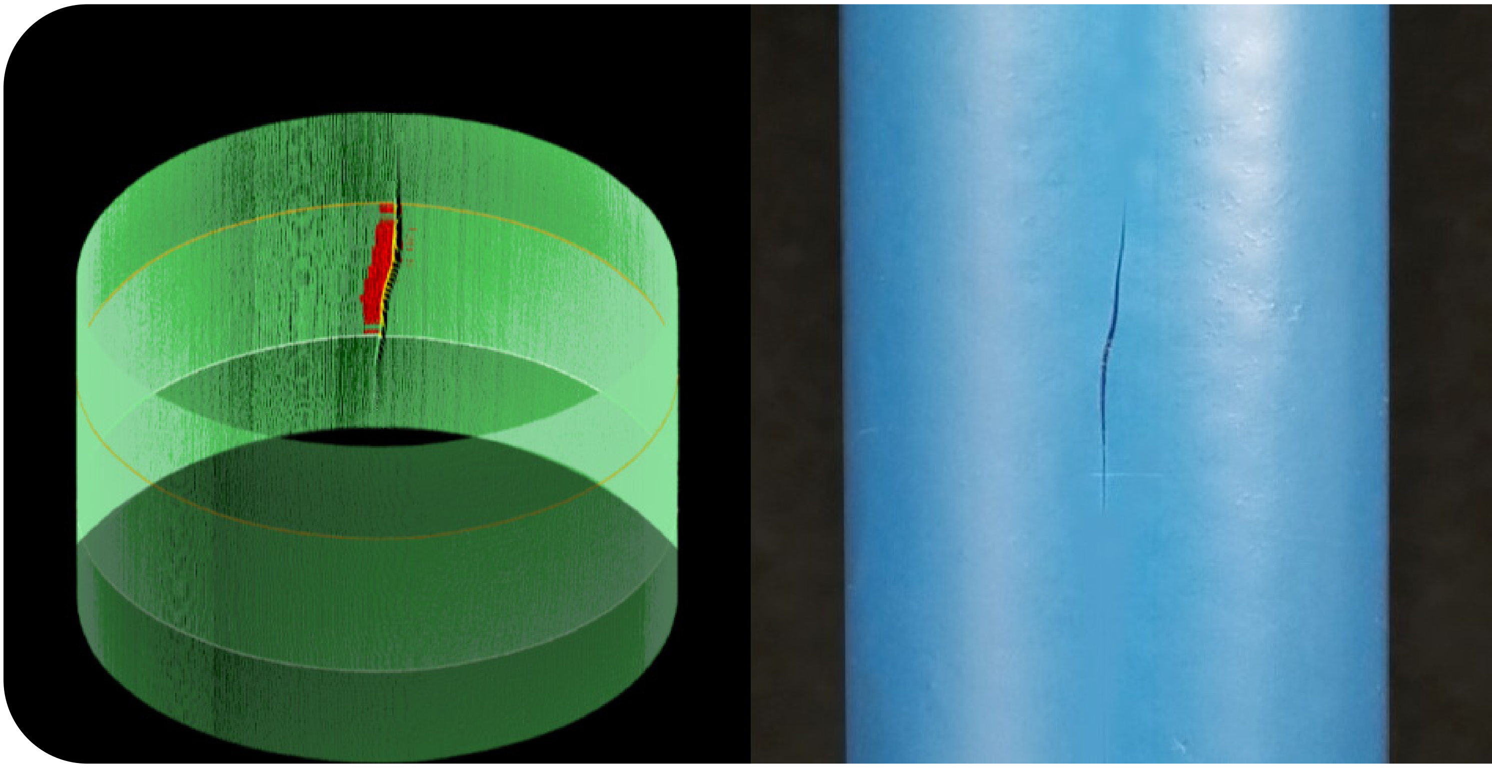


INTRODUCTION with PROBLEM STATEMENT

Continuous, efficient production of top-quality hose, tube, pipe, or cable can be very challenging. A large number of process variables affect the quality of the end product. Process fluctuations can result in surface blemishes that negatively impact the reliability and aesthetics of the material. Surface streaks and jacket slices can occur from process anomalies such as a material buildup on an extrusion die or rubbing against a surface during production. Braid, yarn, and wrapped hose can experience defects in the braid or wrap process that damages the structural integrity of the product. Defects can result in a costly return or loss of future sales if the product gets out the door. Therefore, inline inspection and flaw identification is critical to ensure that the customer only receives top-quality products.

With this constant drive to improve process efficiency and product quality, there is an ever-increasing need to boost inspection performance. End consumers of high-dollar hose, tube, pipe, and cable demand consistent and quality product. This necessarily results in a tightening of product specifications and tolerance for defects. However, with tighter-tolerance inspection comes the increased risk of false-positive flaws and increased required inspection coverage. This is especially true when the end goal is continuous, uninterrupted production, as unexpected downtime can seriously affect your bottom line.

Traditional inspection methods, such as laser micrometers, eddy current testers, and spark testers, have become inadequate for inspecting these tight tolerance applications. All of these methods face debilitating challenges when attempting to perform 100% continuous inspection.

Newer methods have recently hit the inspection market, one of which being inline camera inspection. While these devices are substantially better at inspection than traditional methods, they suffer from challenges that make them impractical to use in many production environments. These challenges include setup difficulties, environmental interference, image exposure time, and the inability to distinguish text on a surface from a surface flaw. Product typically must be uniform for defects to be easily detected in a vision inspection system.

Oftentimes, companies resort to human tactile and visual inspection as this results in more reliable defect detection than the previously mentioned inspection methods.

Ultimately, to achieve 100% real-time inspection, the inspection equipment must be able to detect surface flaws while ignoring text, labels, wraps, and other surface variations that are typical during production. This is the niche that laser triangulation fills. Advancements in laser triangulation inspection have made it possible to fully automate inspection and measurement with one technology, thereby eliminating reliance upon operator tactile and visual inspection, dramatically increasing reliability, efficiency, and safety of production.

BACKGROUND

There are advantages and disadvantages to every type of inspection method, and some methods are better suited to certain types of applications. When it comes to tight-tolerance, high-speed continuous production of round, opaque and translucent product, laser triangulation is the superior inspection method. Other inspection methods simply cannot perform at the required level due to the variety of challenges they face when attempting in-process 100% surface inspection.

Mechanical Detection

Mechanical detection methods, e.g. line breakers or trigger rings, are used to prevent massively oversized flaws from getting through to an end user. When a continuously produced product experiences a massive lump or oversize flaw it will physically contact the line breaker which will trigger the line to stop. Mechanical detection methods will only detect flaws large enough to touch the detector ring. Flaws smaller than the ring, including slit and pit style flaws, will all be missed with a mechanical detection system.

Laser Micrometers

Laser micrometers can achieve measurement rates in excess of 100,000 Hz. Measurements are repeatable, with less than 2.5 µm measurement variation on static product 1 mm in outer diameter. However, micrometers are not the ideal solution when surface inspection and measurement accuracy are critical. Micrometers are shadow-based systems, meaning they have dead zones, or blindspots, where product is not measured. Additionally, this means that orientation of the product in the measurement field could make the difference between detecting and missing a flaw.

In order to reduce the size of dead zones, more axes of inspection can be used at different orientations around the product. While adding more axes reduces the dead zone size, laser micrometers will never be able to detect surface indentations or flaws hidden in this shadow. Surface pits, slits, or irregularity from a perfect ellipse are all missed by a shadow-based measurement system.

Laser micrometers are best used for applications with less critical tolerances or in cases where the larger expense for a better flaw detection system cannot be justified. Laser micrometer systems are around 5x less expensive than camera and laser triangulation systems, but can be 50x less capable of detecting lumps/bumps and infinitely worse at detecting pits and slits. For more information on the limitations of measurement accuracy related to laser micrometer systems, see the white paper on In-line OD and Ovality Measurement.

Lump and Neckdown Detectors

Lump and neckdown detectors work by projecting a sheet of light onto a sensor and measuring the difference in light the sensor measures due to the shadow cast by product in the field. These devices work similar to a laser micrometer, measuring the shadow caused by a part in the field of measurement. Being shadow based, lump and neckdown detectors cannot detect pits or slit type flaws. They are not 360 inspection devices.

Eddy Current

Eddy current inspection is mainly used to identify cracks inside the walls of metal pipes. Because they monitor for changes in a material's conductivity due to internal defects, eddy current testers are unable to detect continuous defects nor any superficial surface defects, such as minor external cracking, scratching, or pitting. This also means that eddy current defect detection does not work on plastics, wraps, or any other non-conductive material. Even on metal products, deeper surface defects are often missed due to the low detection resolution of eddy current devices. Inspection speed is also fairly slow for these devices, requiring slower line speeds for detecting smaller flaws. Eddy current inspection is typically visualized as a waveform on a graph with spikes in the graph indicating a flaw is present. This limited feedback can make it hard to verify the presence of a flaw.

Eddy current devices are for defect detection only; they do not measure dimensional characteristics such as outer diameter or ovality. Therefore, other devices or checks are typically needed to supplement eddy current testing to ensure quality product is supplied to the end user.

Spark Testing

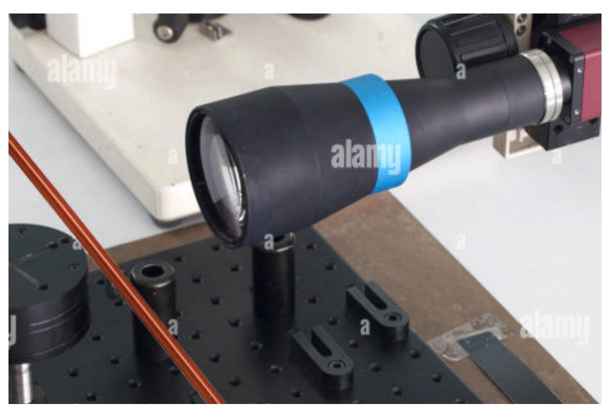
Spark testing is used to detect breaks and thin spots in the jacket of a wire. Products being inspected by spark testers must be electrically conductive on the inside and electrically insulated on the outside, meaning that spark testers are mostly used in specific wire & cable applications.

Spark testers rely on metal chains hanging around a product, touching the surface. Product must be cured or set before entering the spark testers to prevent permanent deformation due to contact with the chains. Spark testers miss lump and bump style flaws and do a poor job of detecting indentations if the insulation is still thick enough to prevent a spark. Gels, lumps, and scratches in the jacket extrusion are all undetectable with spark testers.

Spark testers are for defect detection only; they do not perform measurement. Therefore, additional inspection equipment is typically needed to supplement spark testers.

Camera Inspection

Camera inspection has gained popularity in recent years as image analysis capabilities have advanced and prices have dropped. Multiple cameras can be used together to surround an object and achieve a 360° view of the part, potentially allowing for 100% inspection. However, when it comes to flaw identification and measurement accuracy, camera systems have significant limitations.



One of the most critical limitations in a camera inspection system is the ability to distinguish between flaws and changing surface colors due to labels or text on the product.

Classification and recognition is required in order to distinguish between a flaw and text when analyzing a camera image. This is an extremely challenging task, often performed by artificial intelligence algorithms, which have not yet been developed to analyze the thousands of images per second required for robust identification and reliable detection of flaws on high speed production lines. Oftentimes camera systems are placed inline before labels or text is added in order to avoid this problem, however this means that the final product is left uninspected, which could result in flaws making their way to a customer.

Camera systems are notorious for being difficult to set up and maintain, as they are very susceptible to changes in ambient lighting as well as image blur, due to the relatively long exposure time required for cameras to see the product. These systems are also similar to laser micrometers when it comes to measurement accuracy. Camera systems measure using similar principles to laser micrometers, not taking into account the full 360 view of the product when making measurements. Measurement accuracy is therefore greatly affected by part orientation.

It is due to these many limitations that many production environments find camera systems do not work for their needs. For more information on the limitations of measurement accuracy related to laser micrometer systems, see the white paper on In-line OD and Ovality Measurement.

Operator Inspection (Tactile and visual inspection)

AA common theme in continuous production environments is to have operators check for defects with their hands and eyes. Preceding hand inspection, in-process inspection with laser micrometers and camera systems are used for defect detection. Invariably these users discover the extreme difficulties of these systems and resort to an operator hand-checking product. Hand-checking product has proven to be the most reliable method for detecting flaws when compared to the above methods. However, there are major downsides to checking product by hand. If the check is being done during a secondary process (after production), it can be extremely time-consuming and costly to perform the inspection. If the inspection is done inline by running product through an operator's hands, it can be extremely dangerous—especially if the product contains metal braids that could break and stick out through the jacket. Hand detection is also extremely subjective and tedious. In terms of visual inspection, an operator's ability to see small defects will diminish over time as eye strain and fatigue increases. In terms of tactile inspection, an operator who gets cuts on their hands will become less capable of detecting flaws in the future. Wearing protection like gloves could prevent injury, however it also dulls the operator's senses and could prevent them from detecting flaws in the first place. Inevitably, flawed product will slip through and make its way to the customer.

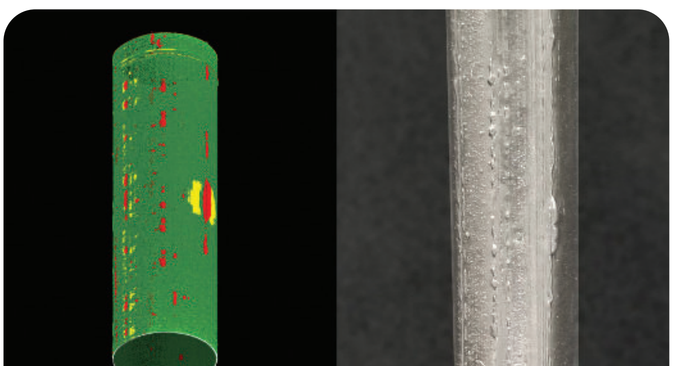
SOLUTION

Laser Line Triangulation

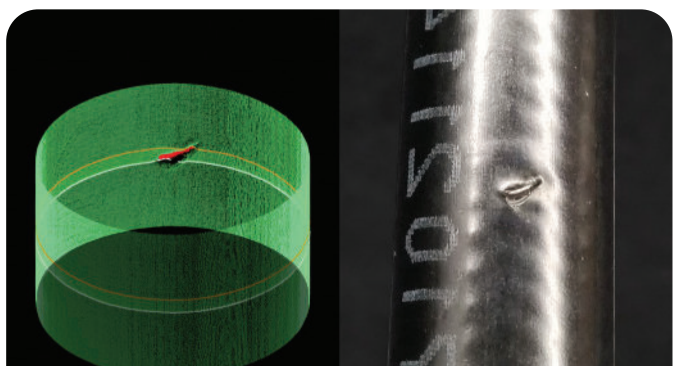
Laser triangulation has been used for decades for object detection, part picking, and basic 3D measurements. With some clever engineering, it is possible to arrange multiple triangulation gauges in a ring to effectively measure 360° around an object in the field of view. Synching encoder readings to each profile enables 3D inspection and visualization of the entire product. Recent improvements in laser triangulation technology have allowed for processing speeds to reach in excess of 10,000 Hz with many thousands of data points measuring the profile of the product per measurement, enabling detection of flaws as small as 5 µm on moving product. While laser triangulation is currently limited to measuring opaque and translucent product, it has many advantages over the previously described inspection methods.

Triangulation technology enables true 360 defect detection and measurement regardless of the products orientation in the measurement field. There are no dead zones with laser triangulation which are inherent with laser micrometer and eddy current devices.

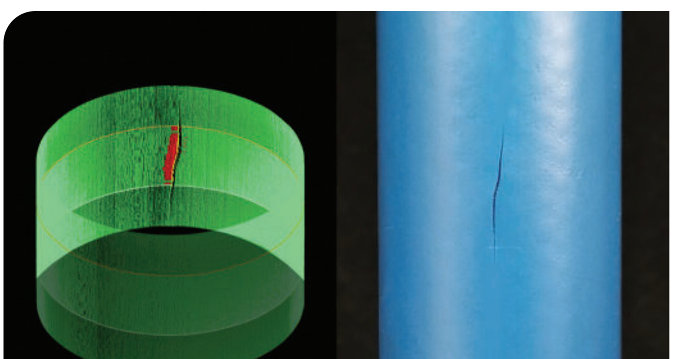
While Camera systems also have 360 inspection, they suffer from other debilitating issues that do not exist in laser triangulation. Due to its use of high-intensity laser light, laser triangulation has significantly less motion blur compared to camera systems. This is due to the fact that less exposure time is required for triangulation systems, as compared to exposure times required to see LEDs or other lower-intensity light sources used in camera systems. This ultimately results in a quicker snapshot of product for triangulation, allowing for smaller flaws to be detected. Laser triangulation is less susceptible to changes in ambient lighting conditions when compared to camera inspection systems. Since laser triangulation uses a brighter light source than LED based camera inspection systems, lower exposure times can be achieved, reducing the risk of detecting ambient light and disrupting detection capabilities.



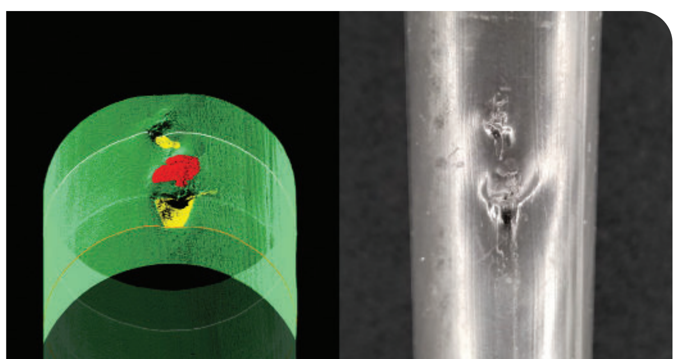
Lumps, Blisters



Braid Breaks, Wrinkles



Slits, Cracks



Pits, Scratches

Many products have text and labels applied before the desired inspection location. Camera systems struggle when text and labels are present. Laser triangulation can see the surface variation caused by labels and embossed text, which slightly reduces the effective detection resolution, but the color changes caused by the difference in label or text color compared to the underlying product is not seen by laser triangulation devices. Since laser triangulation measures the contour/outline/profile of the product and inspects for physical surface variation associated with flaws, color changes go unnoticed. This is an advantage that allows for laser triangulation inspection on finished product, after labels and text have been applied without triggering false positives due to the presence of text or labels. Albeit, This also means that laser triangulation cannot be used to identify colors, text, or errors in text as it's simply ignored by the system.

Advanced algorithms can be used to automatically set up system parameters for measurement and defect detection with the click of a button. When a flaw is detected, a 3D image of the flaw is presented in real time for scrutiny by the user. 3D visualization allows users to compare the real product with what the system detected for instant verification. Ultimately, laser triangulation makes it possible to remove operator hands and eyes from the product, without worry that defects are slipping through.

For more information on the limitations of measurement accuracy related to laser micrometer systems, see the white paper on In-line OD and Ovality Measurement.

CONCLUSION

Laser triangulation is capable of providing defect detection and rates up to 10,000 Hz with flaws as small as 5 µm. A laser triangulation defect detection system can be placed at the very end of a production line, even after labels and text are on the product.

When quality is critical, laser triangulation provides a robust solution. If line operators are known to turn off alarm systems because inspection systems produce too many false positives, laser triangulation will bring trust and reliability back into the inspection process. When laser micrometers are inadequate to detect defects, laser triangulation will fill in the dead zones to detect pits, slits, and flaws up to 50x smaller. If camera systems prove too difficult to set up and unable to detect the smallest flaws due to high line speeds and difficult ambient conditions, laser triangulation automatic setup will take the guesswork out of startup, allowing for immediate detection of surface flaws. When operators spend time manually checking product, inline or offline, laser triangulation could replace this difficult and subjective job, letting operators focus on more important tasks.

Laser triangulation can be used to detect defects and accurately measure diameter and ovality, all in one system. It can be set up to measure and detect product defects with the click of a button, and review flaws back in 3D for operator verification. Laser triangulation is the most capable defect detection and measurement technology on the market.

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