PRECISION IN EVERY PIXEL

The Power of CT Scanning in Product Testing, Evaluation, and Identification

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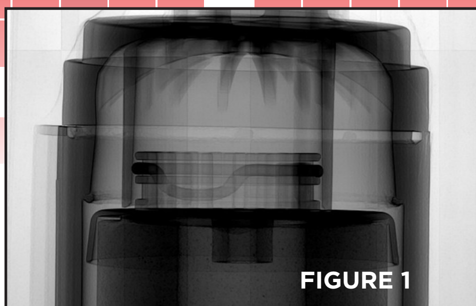
FIGURE 1

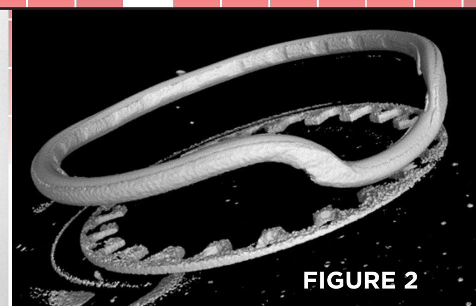
FIGURE 2

FIGURE 3

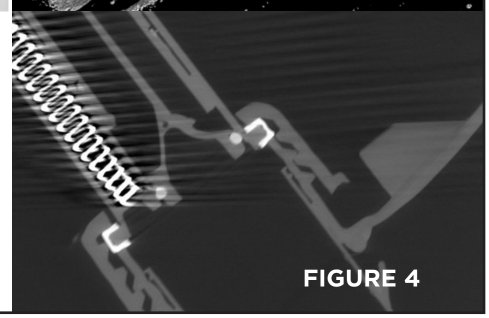
FIGURE 4

In today's consumer world of online purchasing through third-party sellers, peer-to-peer commerce, and the ever-evolving retail landscape, the market is filled with all manner of products. From consumer goods to manufacturing and industrial components, the products we use are everywhere, which means precision and reliability are paramount. When one of those items is alleged to have failed- causing injury or property damage, having the right tools can make all the difference when verifying authenticity, conducting failure analysis, or assessing material integrity.

Originally developed for medical diagnostics in the 1960s, CT (Computed Tomography) scanning is now a powerful tool used to non-destructively authenticate and evaluate original manufactured products. From the manufacturing floor to post-failure analysis, CT scanning provides a detailed view of the internal structure of a product in both 2D and 3D images, revealing a trail of breadcrumbs that an investigator can utilize in their analysis.

BATTERY ANALYSIS AND IDENTIFICATION

Battery design and performance rely heavily on precise internal structures, where even millimeter-scale differences can dictate whether a battery functions properly or fails prematurely. With evolving designs aiming to pack more energy into smaller spaces, the need for high-resolution inspection tools like CT scanners has become critical. This technology enables visualization of both macroscopic and microscopic details, including electrodes, separators, and current collectors. By comparing CT scan data from different battery designs, manufacturers and investigators can identify variations in internal structures, optimize component arrangements, and enhance safety and performance.

CT scanning can also be a useful tool for battery product identification, helping to differentiate cell types and potentially detect internal defects like cracks, voids, or delaminations. It may reveal manufacturing inconsistencies and monitor structural changes during charge/discharge cycles, offering insights into degradation and failure mechanisms. As a non-destructive technique, CT scanning can also help to assess whether battery cells and packs meet design, safety, and performance standards.

PRODUCT AUTHENTICITY

On the mechanical side of the equation, CT can be utilized to view the internal construction of anything from a complex hydraulic manifold to something as seemingly benign as a consumer water filter. The CT scanner can be used to identify assembly defects such as misalignment, cross threading, missing components, overtightening of fasteners or mating parts, and foreign object debris. They can also be used on a more granular level to analyze dimensions down to millimeter or micron resolution, depending on the calibration and experimental setup. Dimensions, layout, and fit are each key ingredients in the recipe used to identify and evaluate the theoretical performance of a product and can be further used to evaluate whether the product is genuine or counterfeit.

Consider the image of a counterfeit water filter (figure 1). This filter was marketed as a genuine name-brand product certified to multiple industry standards, with convincing labeling intended to deceive consumers. To the naked eye, it may look like a viable product. Peel back the curtain with the CT scanner, however, and the true quality of the counterfeit is revealed. Most notable is the deformation exhibited on the internal O-ring. The purpose of this internal O-ring is to seal the passageway between the filter media and the housing. The pictured condition of the O-ring (figure 2) would allow for water to bypass the filter media, negating the entire purpose of the water filter without the consumer having any idea.

In addition, when compared to a genuine filter, the CT scanner can be used to reveal key differences such as filter media volume, housing wall thicknesses, internal flow paths, etc., all of which are able to be observed and measured without ever removing the filter from its original packaging. Each of these “design fingerprints” can be used to compare the differences between engineering drawings, known-genuine products, and suspected counterfeit products.

MATERIAL IDENTIFICATION

One signature that may distinguish a genuine component from a counterfeit can be the materials comprising the component itself. Different materials respond differently to X-rays at the atomic level, and these distinctions can be discerned from a CT scan. Consider a 5-gallon gas can with a threaded spout assembly. There are several individual components that make up the spout system. The way that these components fit together is essential to understanding how they will perform in service. Similarly, the interaction between the different materials within the assembly may also change the performance of the entire product.

Take a look at the regular image of a spring-loaded gas can (figure 3), and the CT image of that same gas can spout shown in (figure 4).

There are at least four distinct materials identifiable in the image. Just like the bright white bones of a medical X-ray, a bright white appearance is due to high X-ray absorbance, meaning less X-rays make it through the material. The high X-ray absorbance of the metal spring makes it quite obvious in the photograph. The circular cross section of an O-ring, designed to prevent leaks from the gas can, shows up as a light gray because it has a distinct X-ray absorbance compared to the materials surrounding it.

Another bright material is the “fluoropolymer” gasket. This material has the square C-shaped cross section as shown in (figure 4), where it fits over the end of the spout. This material contains fluorine, which interacts with X-rays to appear brightly. A rubber O-ring can be seen near the base of the spout that does not appear as brightly as the fluoropolymer. The difference in the material type and its chemical makeup has resulted in a different appearance in the CT. Using CT in conjunction with other materials analysis techniques like Fourier Transform Infrared Spectroscopy (FTIR) and materialography can lead to a precise determination of the specific materials being used in a product. Why settle for “plastic” when you can know it’s high-density polyethylene?

Notice that the alignment of the threads between the gas can and the cap can be evaluated while the components are in place. Not only have the different materials been identified, but also the shape, compatibility, and location of the individual components.

CONSUMER MODIFICATIONS

While the previous examples focused on CT scans of off-the-shelf items, the same principles can be applied to products that have been altered during service or otherwise manipulated after use. One such item is a common material comprised of rubber, fabric, and metal: a tire. Rubber, steel, and fabric have very different responses when subjected to an X-ray source, which makes them distinguishable when combined in a tire and subjected to a CT scan.

In this particular case, the initial tire construction was not under question, but the tire had been previously repaired due to a puncture developed during service. According to recommended industry procedures, tire repairs should contain both a plug and a patch, should be implemented only in the tread or crown area that makes direct contact with the road, and should not be made if the damage extends into the shoulder/belt edge areas. Here, the observed plug appeared at the shoulder region of the tire and contained no discernable patch accompanying the plug. A CT scan of the repaired tire section was conducted to identify the location of the patch relative to the belt endings of the tire (figure 5).

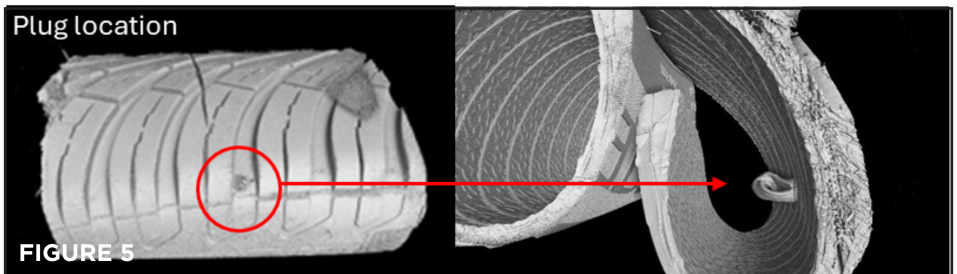

FIGURE 5

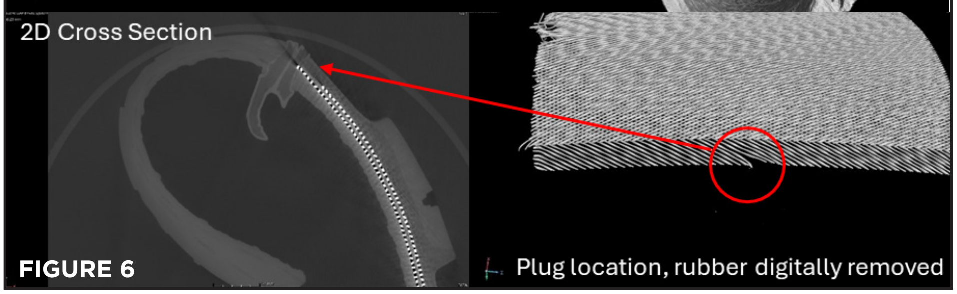

FIGURE 6

Figure 6 shows a cross section of the tire repair and the belt package of the tire with the tread digitally removed. The cross section of the tire highlights the exact location relative to the belt package of the tire. The plug was placed at the belt ending of the first belt which was further confirmed in the 3D reconstruction. The tread was digitally removed by changing the contrast of the 3D reconstruction to focus only on the higher-density metal components – the steel belts- The plug was not contained in the belts of the tire, as suspected, based on the initial observations of the plug location. While the initial observation of the plug location indicated a suspect repair, the CT scan highlighted how far from recommended practices this repair went. The repair contained no patch, was located in the shoulder of the tire, and was in the direct vicinity of the belt edges.

By leveraging CT scanning technology, engineers can non-destructively analyze internal structures, authenticate product integrity, and gain critical insights into material performance. Whether it’s uncovering a counterfeit product or analyzing a patched tire, CT scanning provides an unparalleled advantage in engineering and investigations. As technology advances, so too will our ability to refine, improve, and innovate- ensuring safer, more reliable products for consumers worldwide.

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