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Industrial terahertz scanning for in-line quality control of aluminum caps and sealed closures

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Introduction

There are major advantages to use industrial terahertz scanning to qualify cap sealing. The first is assembly fit. A common request from clients who design and build cap seals is they want to know how the cap and bottle fit together assembled. In the past, the only way to measure the assembly or analyze it for defects was by using a saw to cut through it. Industrial terahertz scanning provides a non-contact, non-destructive alternative. For example, Fig. 1 shows a jar-top where aluminum foil is applied by automated machine for sealing the content. However, many jars fail the quality control check because of defects in the seal. This quality control is done by manual process, as such slow. Moreover, many defects escape human eye and hand causing the defective products to reach the end users. So for automated quality control, a terahertz scanning can check each cap for proper application of the sealing foil in real time. Here, we scan the assembly once with the cap fully assembled. The inline process determines for the perfection and automatically eliminates the ones that are defective.

The defective sealing and leaks are one of the most frustrating issues to deal with when working with cap closures. One of the reasons is because most of the time, they are invisible to the naked eye. With nanometer resolution and advanced processing software, industrial terahertz scanning can identify hard to find leaks and inspect the defective seals all with the click of a mouse. The circumference of the assembly can be scanned non-destructively and in a 360-degree fashion. Another great feature is that these files can be saved and recalled at any point in the future.

Also, the mechanical integrity is also of concern. When a defect occurs and the mechanical closure is not operating properly, industrial terahertz scanning is the best and fastest way to identify exactly what is going on inside. What previously took days or weeks can now be done in a matter of minutes. The ability to use terahertz vision to see beyond the surface of an assembly and inside its mechanical features is priceless.

Fig. 1. Aluminum foil used for sealing jars shows imperfection around the sealed circumference.

Experimental

ARP has devised a powerful technique for fast scanning for seal defect detection. The concept is outlined in Fig. 2. Either a single beam or a plurality of beams may be used based on the nature of the problem. Usually multiple beam is necessary for simultaneous scanning at multiple points to ensure the consistency of results and/or checking different test points. In all cases a fixed reference is used for comparison and decision making.

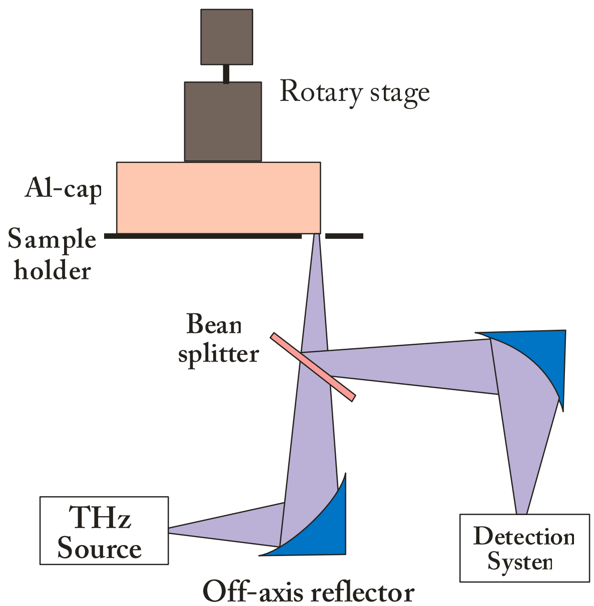

Fig. 2. Experimental arrangement. Either a single beam or multiple beams may be used for simultaneous, multipoint testing.

Aluminum foil sealed-cap samples were kindly provided by Dr. Bruno Bisceglia of the Department of Industrial Engineering, University of Salerno, 84084 Fisciano (SA), Italy. Fig. 1 exhibits a sample where the aluminum seal shows some imperfection.

First, a reference plate was scanned that has a near perfect scan profile. Then the caps were mounted one at a time on the rotary stage as shown in Fig. 2. The scanning beam was focused on the sealed rim of the cap and the cap was rotated at a speed of ~10 mm/s while the reflected intensity with respect to the reference was captured. Samples 1 through 11 were scanned in an identical fashion, one at a time.

Results and discussion

Fig. 3 shows the results of individual scan. As can be seen from the plot, the reference produced almost a straight line scan. The plot (Fig. 3) is $|R_{ref} - R_{Sample}|$over the circumference where the aluminum foil seals the jar. Here, R_{ref} is the scan profile of the reference and R_{Sample} is the scan profile of a sample. Each scan profile shows varying degree of imperfection. It is seen that the higher the difference in reflected intensity with respect to the reference, the higher is the damage and/or surface roughness. Thus, the results indicate a straightforward means for devising a quality control model. However, this should be verified via further (rigorous) experiments and a model may be derived for routine quality control operation. The method is non-contact with adjustable stand-off distance. It is likely that different model formulation will be necessary for different foil-substrate combinations.

A question may arise that, “could the procedure be done with regular laser?” The answer is no. We have tested different systems but without terahertz there is not enough specificity. Further, it is implied that similar procedure can be developed for any sealed cap inspection for various industries such as food and drinks, pharmaceutical, etc.

In summary, non-destructive and non-contact terahertz inspection system may be effectively and conveniently used for a variety of industrial inspections. Thus this technique has the potential for replacing the current inspection tools that require time consuming procedure.

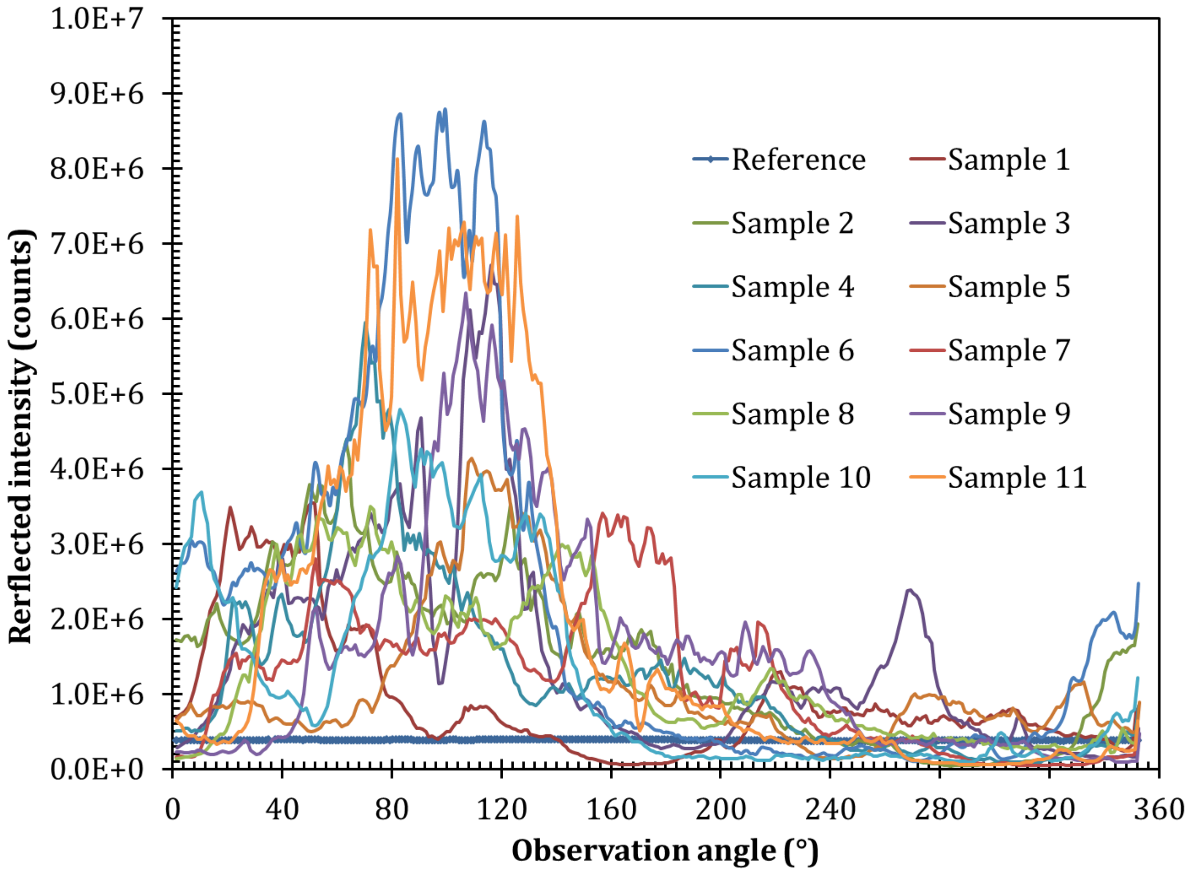

Fig. 3. Plot of scans of the circumference of several samples with respect to the reference.

Fig. 4. A terahertz surface image of a sample showing details surface morphology. Defective and non-defective regions are clearly visible.

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