White Paper

CI-VISION
Vision Inspection

Round Consumer Packaging

Vision Inspection Technology Options

Manufacturers seeking a vision inspection system for round, un-oriented containers have two inspection techniques from which to choose. By studying these inspection methods and comparing them to their needs, manufacturers can find the system that is right for them.

Contents

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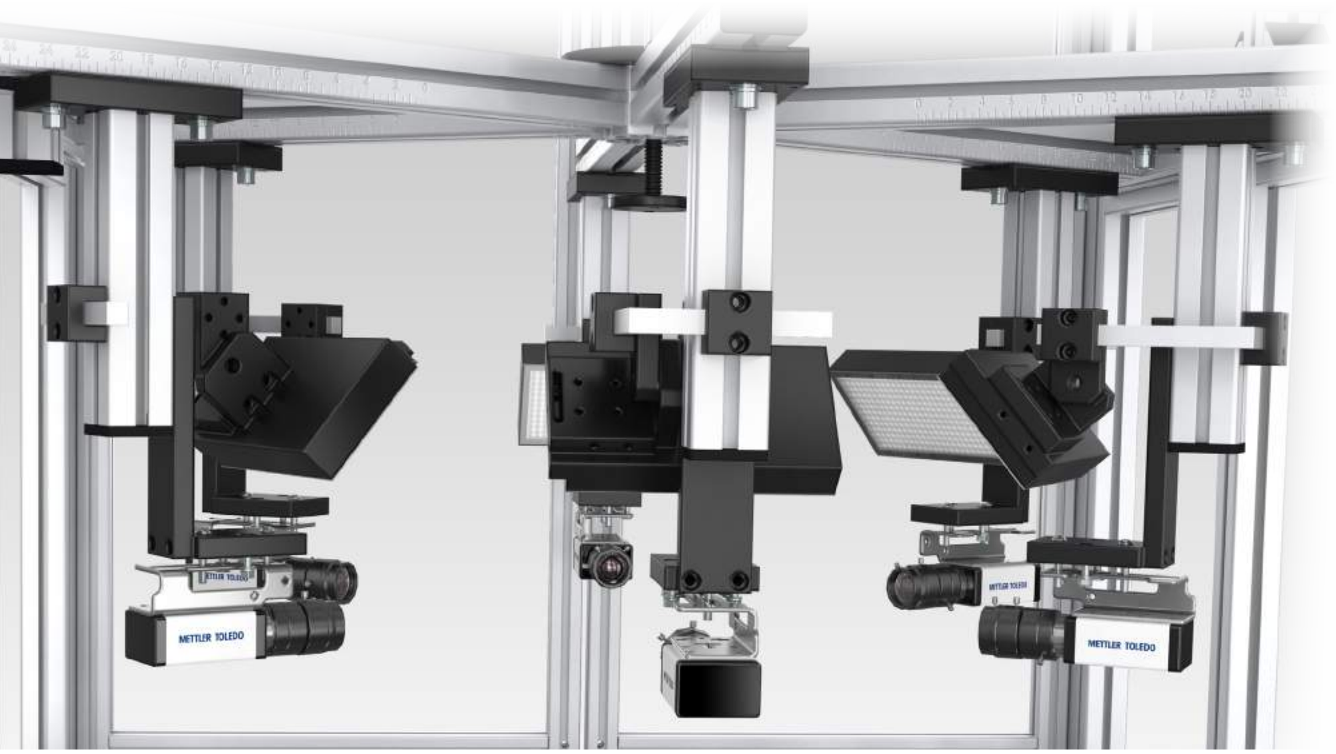
1 Introduction

As more manufacturers choose vision inspection as their preferred quality control solution, the machine vision industry continues to develop new ways of inspecting containers of every shape or size. One of the major developments in vision inspection has been the ability to inspect round, un-oriented product labels for position and quality.

Performing 360° inspections requires a multi-camera system. Cameras are arranged to capture a panoramic view of the product surface, and the images are processed in a way that allows inspection software to treat them as inspection images of flat, oriented products. This white paper compares two methods for 360° product inspection, each with their own advantages and disadvantages: stitching and paneling.

Stitching systems use an arrangement of four carefully calibrated cameras to inspect label positioning on both the X and Y axis. This method is excellent for manufacturers of products which require precise label placements, such as products with multiple labels. The drawbacks of using such a system, however, include longer processing times, a lengthy calibration process that must be repeated for every product size, a risk of false rejects when inspecting graphical information or barcodes and require frequent maintenance.

Paneling systems use multiple cameras to produce overlapping images of important inspection elements such as alpha-numeric text, graphics and barcodes from multiple angles. The system then selects the best possible views of each element to inspect, which significantly reduces false rejects. Paneling is not able to provide precision measurements of label position as with a stitching system, but it carries the advantage of a far easier calibration process, more accurate graphical and barcode inspections, the ability to inspect products that vary in size, a faster operating speed and a much less intensive maintenance schedule.



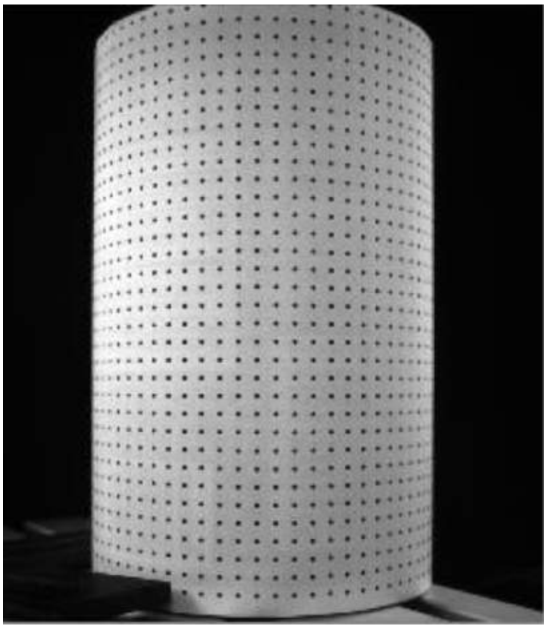
2 Inspecting Round Containers

When inspecting a round container, vision inspection systems have a few additional challenges to overcome which are not present in flat product inspection. Round products moving down the production line are free to shift and rotate as they approach the vision system. As a result, there is no way of knowing which camera will be facing the important inspection element (such as the label graphic or the barcode) when it passes through the inspection system.

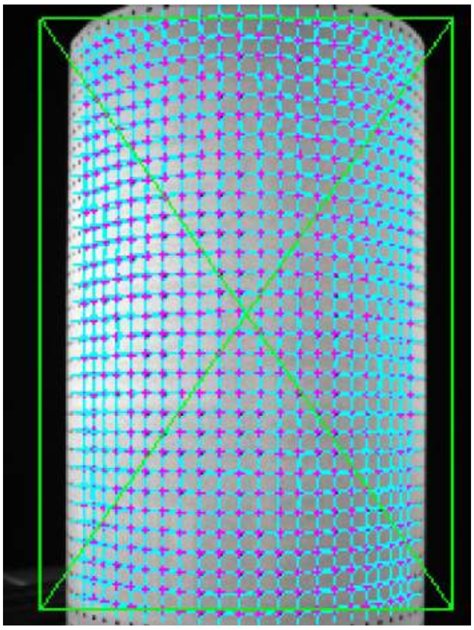
To get around this problem a 360° vision system must have a method for arranging multiple images into a single area of inspection. Accomplishing this involves placing cameras at specific angles and distances from the production line to capture the entire surface of the product container. Depending on the number of cameras, the system may image sections of the container surface multiple times. These resulting images are then flattened out by the image processing software and treated as one large image by the inspection software.

Flattening Curved Products

Flattening an image of a curved product requires some additional steps to set up the inspection system. The system needs to be calibrated to understand the height and radius of the product. This is accomplished using a sheet of paper with a grid evenly-spaced dots on it. This calibration paper is put around the package of the same diameter as the product to be inspected. The camera captures an image of the wrapped paper, which is then presented to the user.



The calibration grid



The calibration grid with correction tool applied

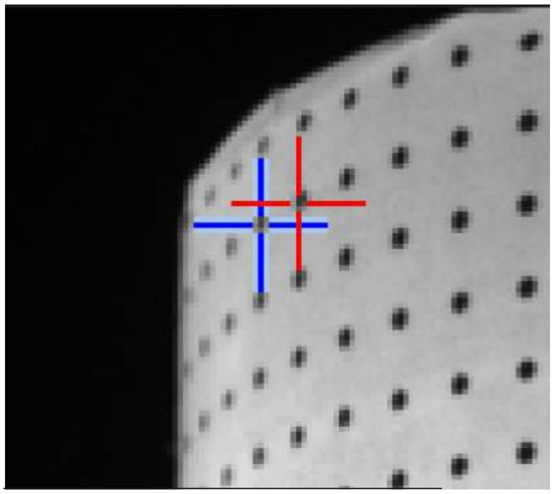
An image of a round, uncorrected container

The same image, corrected

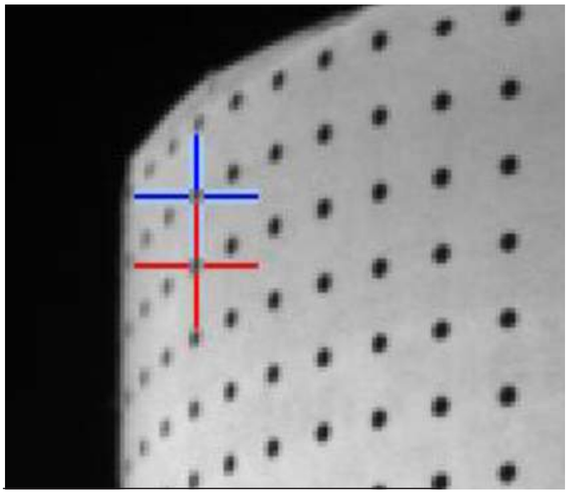
The user inputs the width and height of the grid to be processed, which tells the system the size of the container and determines the area that will be processed.

After determining the grid dimension, the user then lets the system know how severe of a curve it is expected to correct. This is accomplished by manually selecting one of the dots on the grid and then telling the system which dot is directly to the right and which dot is directly below it. This essentially tells the software how much the system will need to warp the image in order to flatten it out. Provided all products being run on the production line are the same size and shape, the system only needs to be calibrated once. Otherwise the system must be calibrated for each product size.

As powerful as this technology is, there are some limitations. The flattening of each image is impressive, but the edges of each container may still suffer from slight distortion. This means that inspection elements on the edge of an image may not appear as clearly as the inspection requires. Flattening out the image, however, is only the first step in the process of inspecting a round image. The next step in the process is where the differences in inspection techniques come in.



Users must tell the system which dot on the grid is to the right of a selected dot...



...and which dot is directly below it

3 Stitching: More Precision

The ability to correct for curved surfaces is all well and good (and very useful) but the question of how the system is supposed to locate a given inspection element on an un-oriented container remains. The most common method is known as stitching. Stitching utilizes four cameras placed so their individual fields of view are at 90° angles to one another. This gives a 360° view of the container surface, but there is still no way of knowing which camera needs to look for a given inspection element. Stitching creates a fifth image out of the four camera images to give the inspection software something to run inspections on.

When the cameras are positioned, their fields of view will overlap slightly, allowing the system to compensate for any minor distortion that occurs at the edges of the camera's view. These images are distorted to compensate for the curved surface of the product. The system needs to put the images it receives into a recognizable order; this is accomplished by looking over the images for a particular reference point selected by the operator. Once it locates that first reference point, it knows what to call the "first" image, then proceeds in order from that image to arrange the remaining three. The images are then stitched together to form a single image; upon which the rest of the inspections tools run.

The system needs to arrange the images in part because otherwise the rest of the inspections would not be able to perform. Remember, there is no way for the system to know what part of the label each camera is going to see as a product moves through the system, and the running inspection tools that search the whole image would be prohibitively slow. Defining set areas in which each inspection tool runs allows the system to run faster. By stitching a complete image together, the system is able to perform precision measurements of the label's position on the container along both the x and y axes. Labels with unique shapes which must be placed in specific positions on a container can be properly verified by the system, as the final stitched product is treated as a single flat inspection surface.

There are some drawbacks to the stitching method, and almost all of them have to do with the high degree of setup required. Stitching requires that the four cameras be precisely positioned so the fields of view properly overlap, as otherwise the final stitched image will not accurately reflect the contents of the label, resulting in reduced inspection reliability. The precision required to stitch a complete image that is accurate means that calibrating the cameras and software takes at least 52 steps, and must be done for every container size. This allows the system to create a 3D model of the object, which it uses as a reference when assembling the stitched image. The process also compensates for any alignment issues which may occur with regards to the camera placements. Those container sizes cannot vary too much among one another, because otherwise the limited fields of view on the cameras will not overlap properly, or the calibration will no longer be valid for a smaller product size. This will result in either a blurred or incomplete final stitched image, leading to false rejects.

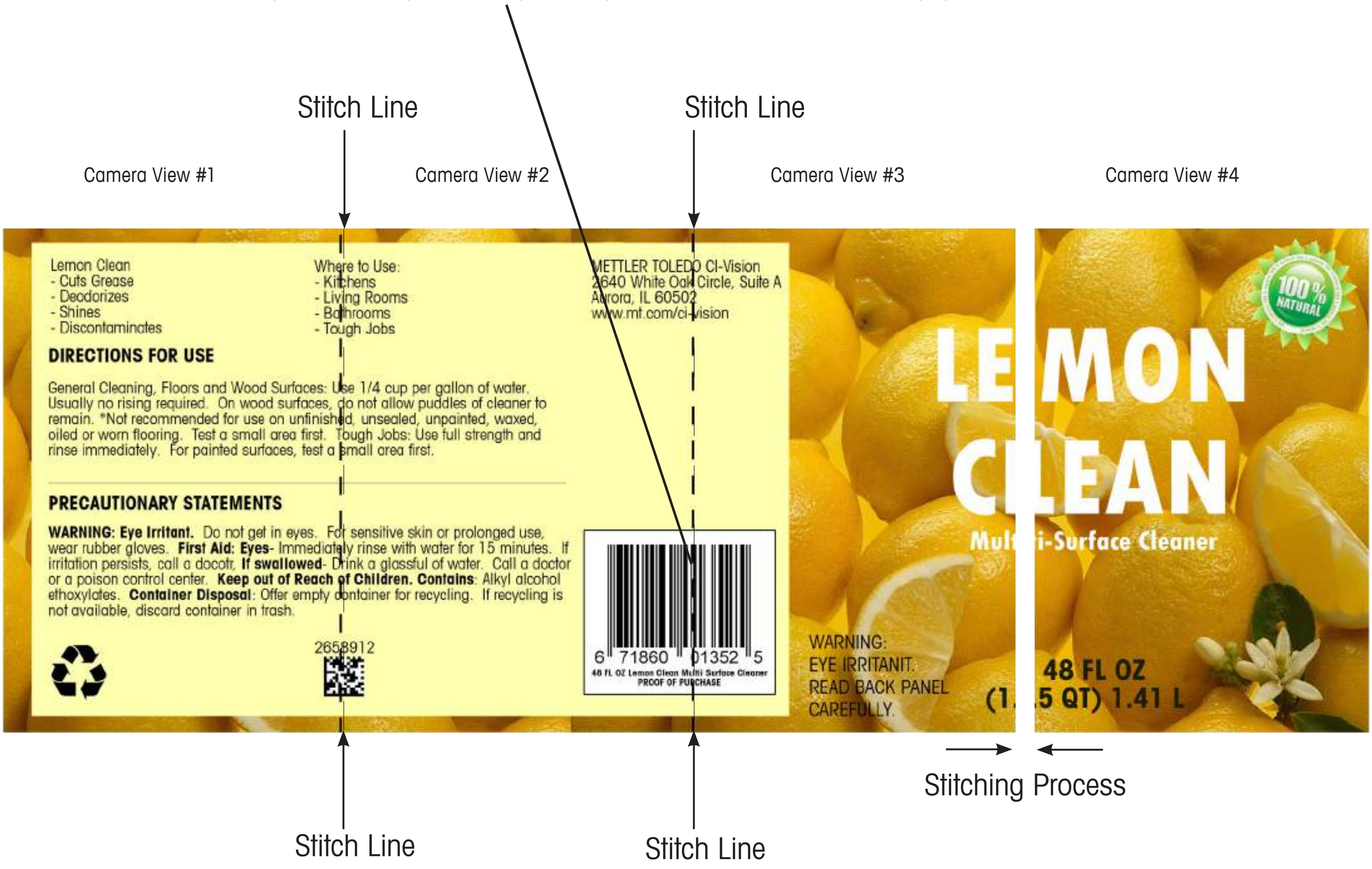
Operators will also find that stitching systems require careful and frequent maintenance, especially in a busy manufacturing environment. Anything from jostling of the system to vibrations on the conveyor can knock the cameras out of alignment or move the product around too much for the system to accurately stitch together an image, resulting in poor performance.

The other drawback is the stitching process itself. The actual stitching process takes a considerable amount of processing power and time to perform accurately. This leaves the system less time to run the actual inspections on a product and transmit a rejection signal if the product label is defective. With modern processors this may only be a matter of a few milliseconds, to be sure, but it limits the speed at which a traditional 360° inspection system can run and reduces the total number of possible inspections the system can handle on one container.

Another more pressing issue with a stitching inspection system is the problem of assembling the image in the first place. As previously stated, the inspection software looks for a predefined reference point to decide which view to consider "first" and builds the rest of the image from there. If the reference point falls between two cameras, the system has to be able to recognize this problem and correct for it. Other important inspection markings which fall between cameras will suffer from stitching lines: rows of pixels which the system discards during the inspection process (the reason the four fields of view of the cameras are set up to overlap slightly is to account for and mitigate this effect). The final image will have stitching lines present on it no matter what, however, which means that—for example—a 1D barcode may gain or lose lines, resulting in an incorrectly triggered rejection.

All told, the stitching method of 360° inspection is the best (and currently only) method for precision inspections of label positioning, but manufacturers without a need for precision label positioning on their product packaging should consider alternative methods of label inspection.

A barcode line of a few hundred microns will only be represented by a few pixels, so it is easy to imagine the stitching process erasing a line entirely—creating an unreadable barcode or even changing the barcode's value.



4 Paneling: More Flexibility

Stitching has a lot of drawbacks, but it is invaluable for manufacturers who need to have precisely placed labels. Manufacturers with wrap-around labels, sleeves or pressure sensitive labels which do not have the same need for precision placement and will find that inspection systems using stitching do not seem to be worth the time and money they require. Fortunately, stitching is not the only available method for inspection of round, un-oriented products.

Paneling is an alternative 360° inspection method which shares some functions with stitching, but with several important differences. First, and most noticeably, a vision inspection system utilizing paneling requires more than four cameras (for the purpose of this paper, we will discuss a six camera paneling system). The cameras are arranged so that the field of view of each camera overlaps with its neighbors by about 20° (in more practical terms, the overlap is about the size of a 1D barcode). This provides an important advantage to paneling systems when it comes to 360° inspections: the system will always have a good image of important inspection elements.

Recall that the first step in inspecting a round product is to correct for the curve of the product surface. The correction tool distorts the image to flatten the image out, but it is an imperfect adjustment. The edges of the image will always suffer from slight distortion; the system could run additional, more targeted instances of the tool in an attempt to clean up the remaining distortion, but at a certain point it becomes too time consuming. Overlapping the fields of view eliminates the problem of important inspection elements being caught on the edge of an image, considerably improving the accuracy of the system.

Adding two cameras solves one problem, but presents another obvious problem: namely, that overlapping the images essentially makes stitching together a complete image far more complicated—there are multiple views of too many features to allow a system to easily crop and assemble a complete image. The solution is to discard the notion of stitching together an image entirely. Instead, the system takes each corrected image and arranges it into a series of paneled images.

Similarly to a stitching system, the first step after images are captured and flattened is for the system to determine which image will be designated as the "first" image. There may be multiple images containing the reference point selected for the designation of the first image, but the system will select the best-looking image of the two and then lay the rest of the images out from there.

Much like a stitched image, the system runs the actual inspections on this series of paneled images. The tools have a general idea of where to look for each inspection element, and because of all the overlapping fields of view, there will always be a clear image of each inspection element. The system can choose the best quality view to inspect, greatly reducing the chance that field of view distortion causes a false reject.

One of the other main advantages of a paneling system comes in the setup phase. Again, the overlapping of fields of view plays a large role in making setup easier. The calibration process does not need to account for quite as many variations in product position, because of the additional security of multiple views of the product. As a result, calibration only requires 18 steps rather than the 52 steps required by stitching methods.

Most importantly, using six cameras instead of four gives the system a greater ability to deal with normal variations inherent in product packaging, because it does not require a 3D model to assemble its final image. This ability to deal with larger variations in container size also allows the system to handle shifting or jostling products on the line better than a stitching system. The system does not need the images to line up perfectly, because it is not assembling a complete image, merely arranging the images relative to one another.

Keeping a stitching system in perfect working order requires intensive maintenance and careful re-calibration of the system on a regular basis to compensate for environmental factors in a production environment. Paneling systems will require occasional maintenance, but the additional cameras and overlapping fields of view act as a sort of safeguard against everyday disruption, as shifting products will not cause the same sort of problems that manufacturers would see in a stitching system. The paneling tool is also much less processor intensive, which allows the system to operate at higher speeds, better keeping pace with the increasing throughput demands of product manufacturing.

Finally, the cost of a paneling system has several advantages over that of a stitching system. This may seem strange, considering a paneling system has two additional cameras compared to a stitching system and cameras are costly components, but the largest cost of a system is not in the hardware, it is in the software. The stitching tools required to put together are a proprietary technology which took a large amount of time and effort to develop. This results in a significant increase in price for a stitching system. The tools required for paneling, by contrast, are far more commonly used, and the license to use the tools costs much less.

There is one downside to using a paneling system: label positioning inspections are much less precise. The system can perform positioning inspections on the y axis easily, but when it comes to measuring the distance between labels along the x axis, a paneling system cannot produce reliable results. For most manufacturers, however, this is not a major need; their containers have a single label, full sleeve, complete wraparound label or pressure sensitive labels with a higher tolerance for position. Provided the label's x position is within acceptable tolerances, a paneling system will perform more accurately and more reliably than a stitching based inspection system.

Camera View #1

Camera View #2

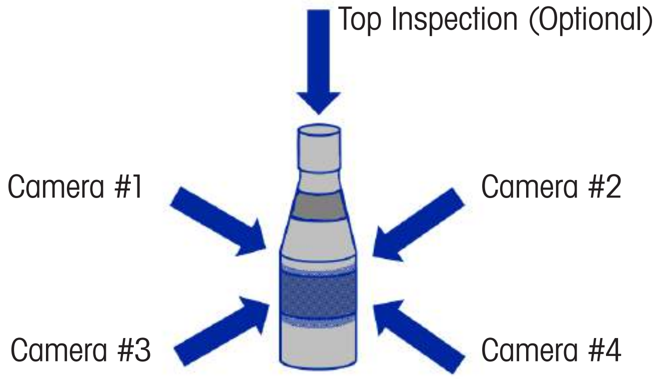
Camera View #3

Camera View #4

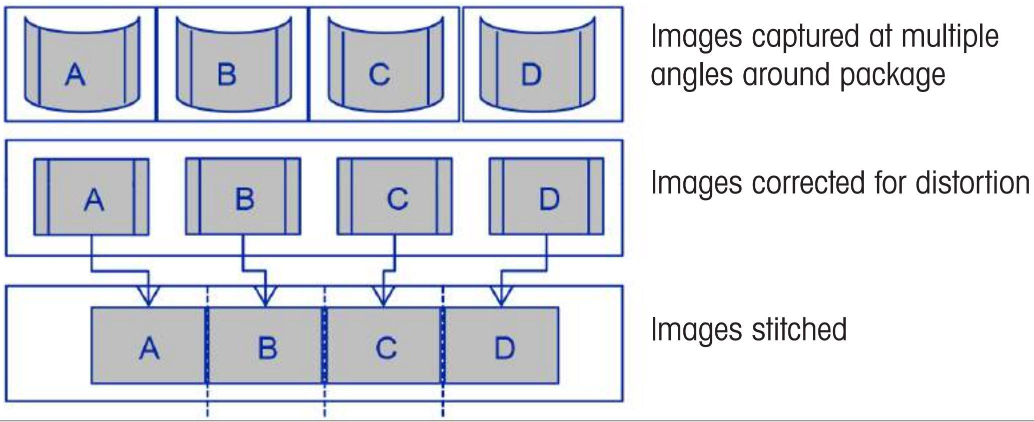
Camera View #5

Camera View #6

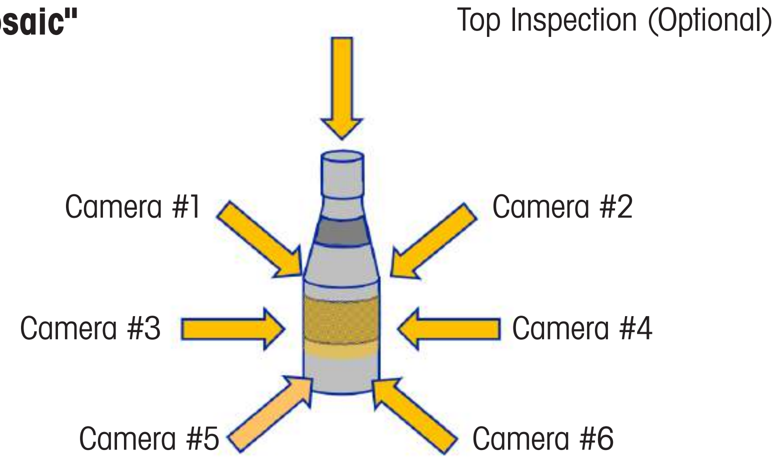
Stitching



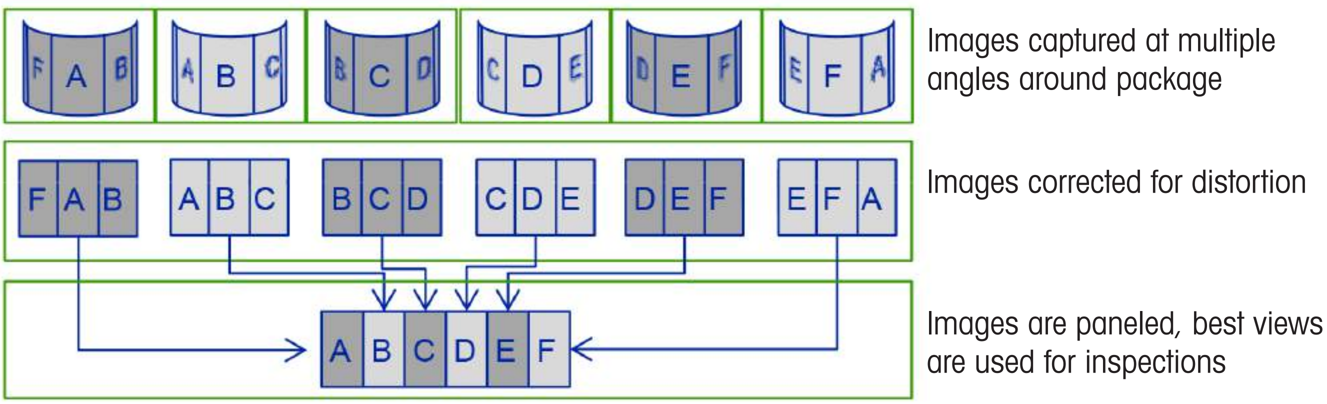
360° inspection stitched



Paneling/"Mosaic"



360° inspection non-stitched

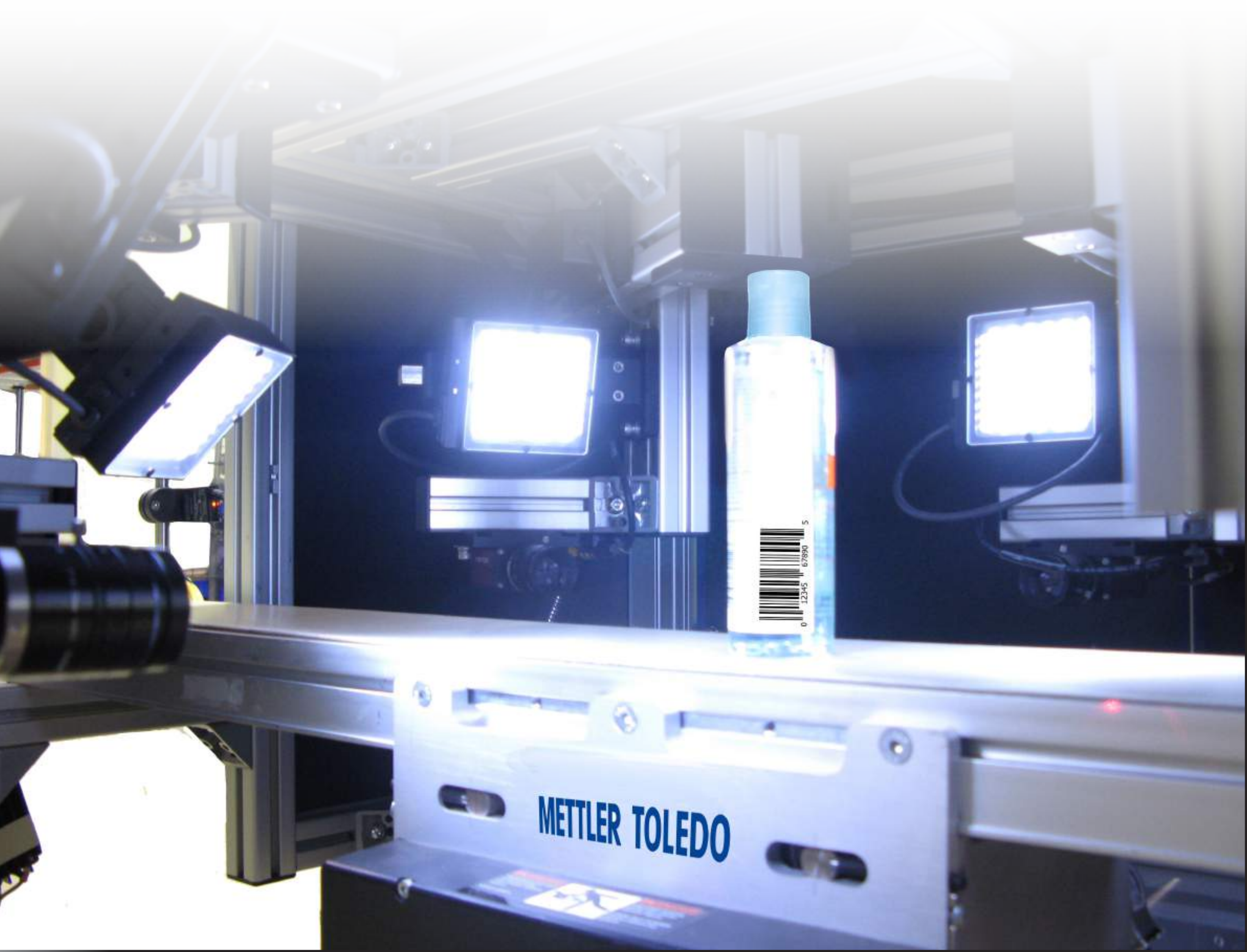


5 Well-Rounded Benefits

Thousands of manufacturers have turned to 360° vision inspection systems in order to improve the quality and presentation of their round, un-oriented products. When choosing a vision inspection system, manufacturers must carefully consider which inspections are most important to their business to help determine which system is right for their needs.

Manufacturers with lower tolerances for label position will find that paneling systems are more than adequate for their needs, while those with a greater need for precision in their label placements will wish to use a stitching system. A paneling system is the best option for manufacturers with a greater focus on label quality and mislabeling prevention.

To get the absolute most out of a vision inspection system, manufacturers need to carefully plan their inspection program and execute installation of their systems with immense care. A proper vision inspection system provider should walk manufacturers through every step of the planning process, ensuring manufacturers not only obtain the right system for their needs, but are given the sort of support and training which such systems require.



Notes

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