Title: NON-DESTRUCTIVE INSPECTION OF MATERIAL IN CONTAINER

Abstract: An apparatus and method for non-destructive inspection of materials housed in containers involves orienting an X-ray beam emitter and detector to direct and detect an X-ray beam at an angle substantially parallel to a sloped surface of the container to be inspected. A first X-ray apparatus is located opposite a second X-ray apparatus, and both the first and second X-ray apparatus are adapted to provide two X-ray beams. This arrangement provides for imaging of the entire area of a sloped portion of the container without any shadow or hidden spots.

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NON-DESTRUCTIVE INSPECTION
OF MATERIAL IN CONTAINER

CROSS-REFERENCE TO RELATED PATENT APPLICATIONS


BACKGROUND OF THE INVENTION

[0002] This invention concerns the non-destructive inspection of materials housed in containers, and more specifically the inspection of such materials using X-ray beams.

[0003] Inspection of various production products has become increasingly important in recent years. Traditionally, product inspection has been limited to physical inspection of the product by a worker on the production line. Obviously, this form of inspection is less than optimal. As such, two more useful devices were developed and became the standard inspection apparatus: a check weigher and a metal detector. Each of these devices has its own inherent limitations, and even the system in combination lacked the ability to provide much information. Therefore, a need exists for an inspection system that can provide more detailed and variable data. The types and breadth of inspection data needed vary from product to product.

[0004] It is well-known to carry out non-destructive inspections of materials, including materials in containers, with X-ray beams. In general, a typical basic x-ray device is a linear array comprising a high voltage power supply to power a x-ray tube wherein a beam of x-rays is directed at the product. The x-ray beam passes through the product to ultimately impinge upon a sensor or sensors, such as a row of detector diodes. Such x-rays devices typically then display an image of the material based on the x-rays. This image can provide valuable information which a normal optical image cannot. The formation of images due to light or X-ray differs. The major
difference is that optical images are created by light reflection on the object surface and X-ray images are formed due to X-rays absorption by passing through a material. Thus, an optical image gives information about the object’s surface and an X-ray image supplies information about the inner structure of the object.

[0005] An X-ray image is a silhouette, where the degree of transparency is dependent on the density, thickness and the atomic number of the material. Using the current technology this information can be separated and coded into a false color. The atomic number information is coded into the hue value of a color image in HIS (Hue, Intensity, Saturation) format. The mixed information about the thickness and the density is coded into intensity of a color. A certain percentage of X-ray energy is absorbed by the material due to a process known as electron ionization. The amount of energy absorbed depends on the density and atomic number of the material. As a result, the detected X-ray attenuation provides a picture of the absorbed energy on the irradiated objects. Due to the absorbed energy being relative to the atomic number, it can be used in the material discrimination process.

[0006] In general, the lower the atomic number, the more transparent the material is to the X-rays. Materials composed of elements with a high atomic numbers absorb radiation more effectively causing darker shadows in an X-ray image. Substances with low atomic numbers absorb less X-ray radiation, hence their shadowgraph appears a lighter color. The absorption of the X-ray radiation by a material is proportional to the degree of X-ray attenuation and is dependent on the energy of the X-ray radiation and the following material parameters: thickness, density, and atomic number.

[0007] A problem encountered when using such apparatus and systems, especially when inspecting food in containers, is that the geometry of the containers often causes undue lines in detector images thereof, which detract from the quality of such images and, therefore, negatively affect interpretations of the images. None of the apparatus and methods described in the above-mentioned patents adequately overcomes this problem. X-ray inspection of food products in glass jars to eliminate broken glass contaminants presents a unique challenge due to the crown typically found in the jar bottom. Single view systems are offered but the coverage on the jar bottom is limited
as this crown will "hide" the contaminant resulting in the fact that the contaminant must be of a size large enough to extend above the crown as viewed by the x-ray system. These systems are designed with a geometry of shooting the x-ray beam parallel to the jar bottom. If the jar bottom were perfectly flat then 100% coverage of the jar bottom can be achieved. The amount of the crown a jar exhibits determines how much of the jar bottom a single view system can effectively inspect. The larger the crown, the less coverage of the jar bottom is achieved. Typical crowns range between about 4.0 mm and about 12.0 mm in height. A single view system well effectively cover, for example, about 40% of the jar bottom for a 4.0 mm crown height. This coverage is reduced as the crown becomes larger, for example, to about 20% for a crown of 12.0 mm.

[0008] Dual view x-ray systems are known where the x-ray beams are at a 900 angle from one and other, both beams being parallel to the jar bottom. This increases the coverage of the jar bottom to between 40% and 80% depending on the crown height. A number of the systems described in these patents employ two or more X-ray beams at substantial angles to one another for producing two or more images that can be interpreted from the two different perspectives. This increases an amount of information available for interpreting the images.

[0009] It is noted that many X-ray apparatus and methods for inspecting food in containers respectively use only one X-ray beam and one detector so as not to unduly complicate structure and image interpretation. Similarly, many such X-ray inspection apparatus and methods that direct beams at conveyed containers, direct the beams perpendicular to the conveying paths. Such a beam, perpendicular to the conveying path, provides a perspective that is most intuitive for image interpretation and that avoids passage of the beam through two adjacent types of materials and two adjacent containers. In this regard, bulk containers are often rectangular in shape, therefore having leading and trailing sides that are also perpendicular to the conveying path. When leading and trailing sides of adjacent containers are close together, an angled beam can pass through the two containers. Similarly, types of materials within the containers are aligned with these sides so that angled beams can pass through two adjacent types of materials.
In addition, such bulk containers often house smaller cases that also have sides perpendicular to the conveying path. Again, these perpendicular sides of the bulk containers and cases cause lines in detector images produced by perpendicular beams that detract from analysis of the detector images.

Thus, it is an object of this invention to provide an X-ray inspection apparatus (as well as a method) that produces an intuitive, easy-to-read detector image of material in conveyed containers; but yet that reduces the effects of lines in the image caused by container sides, particularly for food containers.

**SUMMARY OF THE INVENTION**

According to an embodiment of the invention, an apparatus and method for non-destructive inspection of materials housed in containers are provided. The method includes orienting an X-ray beam emitter and detector to direct and detect a first X-ray apparatus on a first side of a conveyor along which the materials are conveyed. A second X-ray apparatus is located on the opposite side of the conveyor. Each X-ray apparatus is adapted to provide at least two X-ray beams, such as through the use of a dual beam generator, each with a corresponding X-ray detector. In a preferred embodiment, by using two x-ray apparatus located on opposite sides of a conveying line, each having two detector apparatus in association therewith, the present invention is able to provide an improved image of the bottom crown of a container. Preferably, the two X-ray beams on each side of the conveyor are angled 450 with respect to each other (22.50 with respect to the conveyor).

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only, and are not restrictive of the invention as claimed.

**BRIEF DESCRIPTION OF THE DRAWINGS**

These and other features, aspects, and advantages of the present invention will become apparent from the following description, appended claims, and the accompanying exemplary embodiments shown in the drawings, which are briefly described below.
[0015] The invention is described and explained in more detail below using the embodiments shown in the drawings. The described and drawn features, in other embodiments of the invention, can be used individually or in preferred combinations. The foregoing and other objects, features and advantages will be apparent from the following more particular description of preferred embodiments of the invention, as illustrated in the accompanying drawings in which reference characters refer to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating principles of the invention in a clear manner.

[0016] Figure 1 depicts a side, cutaway, elevation of a prior-art X-ray inspection device of a general type with which this invention is used;

[0017] Figure 2 depicts a side, cutaway, elevation of an X-ray inspection device;

[0018] Figure 3 depicts a prior-art image of a type normally produced with the device of Fig. 1;

[0019] Figure 4 is a view of a prior art apparatus wherein a single view is used;

[0020] Figure 5 is a top-view of an apparatus of the present invention having two dual beam x-ray generators on opposite sides of a path of the object to be scanned and each in communication with two detectors opposite their respective x-ray generators;

[0021] Figure 6 is a view of an apparatus in accordance with the principles of the present invention depicting a first view from a first x-ray apparatus;

[0022] Figure 7 is a view of an apparatus in accordance with the principles of the present invention depicting a second view from a first x-ray apparatus;

[0023] Figure 8 is a view of an apparatus in accordance with the principles of the present invention depicting a first view from a second x-ray apparatus;

[0024] Figure 9 is a view of an apparatus in accordance with the principles of the present invention depicting a second view from a second x-ray apparatus; and

[0025] Figure 10 is a view of an apparatus in accordance with the principles of the present invention depicting the composite of the views shown in Figures 5-8;
DETAILED DESCRIPTION

[0026] A prior-art X-ray inspection device 11 of the type normally used for inspecting food materials in containers includes an X-ray tube 10 for producing an X-ray beam 12, an X-ray detector 14 for receiving a portion of the X-ray beam 12 that has passed through a container 16 and generating therefrom an image signal representative of the portion; a conveyor 18 for conveying the container 16 along a substantially straight conveying path 20 in a conveying direction 22; and a shielding tunnel 24. It is noted that in this prior-art system the conveying path and direction, 20 and 22, are substantially straight and that the X-ray beam emitter is mounted at a first fixed position adjacent the substantially straight conveying path. The detector 14 is mounted at a second position adjacent the conveying path on a side of the conveying path opposite to that of the first position at which the X-ray emitter 10 is located so that it can receive the portion of the X-ray beam once it has passed through the container 16. It is further noted that the X-ray emitter 10 and the X-ray detector 14 are substantially directly opposite one another so that the X-ray beam 12 is substantially perpendicular to the conveying path 20 and the conveying direction 22.

[0027] In many such apparatus for inspecting food materials housed in containers there is only one X-ray beam and one detector, thereby reducing complexity and cost of the system and simplifying interpretation of only one detector image. In this regard, a representative detector image for the prior-art system of Fig. 1 is depicted in Fig. 3. As can be seen in Fig. 3, there are two distinct image lines 26 that are caused by a leading side 28 and a trailing side 30 of the container 16. It has been noticed that these lines can be disturbing when people or machines interpret the detector images 32 of the material in the container 16. In this respect, most large food material containers, as well as other types of containers, are rectangular in shape, and therefore have leading and trailing sides that are perpendicular to the conveying direction 22. At the same time, many bulk food-material containers also house smaller cases 34 having sides that are parallel to the leading and trailing sides, 28 and 30, as is shown in Fig. 2.

[0028] The present invention provides a system and method which eliminate the "hidden" areas of the prior art systems by orienting the x-ray beams to be parallel to
the slope of a crown 10 in the container 16. In one embodiment illustrated in Figure 5, system has a structure of two x-ray apparatus 42a and 42b oriented on opposite sides of the conveyor 20 traveling through the system. Each apparatus emits a dual beam at 450 from one and other. Four x-ray sensor devices 14a, 14b, 14c, 14d are placed on the opposite side of the conveyor from their respective tube. This inspection structure with two dual beam tubes and four sensors allows substantially 100% inspection of the glass jar bottom.

[0029] Figure 4 depicts the area of a crown 40 detected by an apparatus of the prior art. The prior art apparatus does not provide adequate detection as it is capable of detecting only a small portion of the area below the crown 40, and the angle of crown creates difficulty in obtaining a clean image of even that area.

[0030] Figure 6 depicts a first view of a four view (i.e. four beams and detectors) system. This view provides a full coverage of 40% of the jar bottom that is on the detector side of the conveyor. The second view shown in Figure 7 also covers 40% of the jar bottom but is at a 450 angle from the first view and thus shifts the full coverage by 450. The combination of these two views results in full coverage of 60% of the jar bottom with an overlap between the two views.

[0031] The third view shown in Figure 8 represents the results of a detector on the opposite side of the conveying line in regard to the detectors shown in Figures 6 and 7. This view provides full coverage of 40% of the jar bottom, opposite the first view by changing the tube/detector relationship such that the x-ray beam is shot from the opposite side of the jar. The result is picking up an additional 20% of the jar bottom for full coverage and adding to the overlap. The fourth view shown in Figure 9 adds the final 20% of the jar bottom for full coverage.

[0032] Combining the four views, as shown in Figure 10, allows for each individual view to be optimized for the 40% of the jar bottom that the view is inspecting and ignoring the 60% of the jar bottom because the addition views will cover that area. Thus an improved image of 100% of the jar bottom is obtained with no shadows or hidden areas.

[0033] The apparatus and method of this invention have the benefit that the image signals generated by the X-ray detector 14a are produced by a beam 12a that is
sufficiently close to a perpendicular beam that an image thereof is not unduly modified from that of a perpendicular beam, as can be seen by comparing Figs 3 and 4. This enables one to interpret the image in substantially the same manner as is a perpendicular-beam image.

[0034] While the invention has been particularly shown and described with reference to a preferred embodiment, it will be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the invention.

[0035] An enhancement of this invention further involves an adjustment structure 38 that allows the X-ray detector 14a to be moved further away from the X-ray emitter 10a in order to provide magnification of an image generated by the X-ray detector 14a and that allows the X-ray detector 14a to be moved horizontally so as to fine-tune collimation. In this regard, it is noted that if the X-ray detector 14a is moved downwardly to increase magnification, it must also be moved sidewardly to ensure that it continues to align with the X-ray beam 12a.

[0036] In addition, an apparatus and method in accordance with the principles of the present invention may further comprise various additional inspection features such as but not limited to check-weighing capability, missing item detector, void detection, and reject stations. The reject station may utilize, but is not limited to, a signal only, an indicator light, a single lane air blast, a single piston side push arm, a vertical side impulse push arm, or a horizontal side impulse push arm.

[0037] Given the disclosure of the present invention, one versed in the art would appreciate that there may be other embodiments and modifications within the scope and spirit of the invention. Accordingly, all modifications attainable by one versed in the art from the present disclosure within the scope and spirit of the present invention are to be included as further embodiments of the present invention. The scope of the present invention is to be defined as set forth in the following claims.
WHAT IS CLAIMED IS:

1. An apparatus for non-destructively inspecting materials housed in a container having a crown with an inwardly sloping surface on a bottom wall thereof, said apparatus comprising:
   a conveyor for conveying said container along a conveying path in a conveying direction;
   an x-ray beam apparatus having an X-ray beam emitter mounted at a first position adjacent said conveying path for emitting an X-ray beam passing through said container as it is conveyed along said conveying path;
   a detector mounted at a second position adjacent said conveying path on a side of said conveying path opposite that of said first position for receiving a portion of the X-ray beam that has passed through said containers and generating therefrom an image signal representative of the portion; and
   wherein said X-ray beam emitter is positioned to direct a portion of the X-ray beam along a path that substantially parallels a sloping surface of the container.

2. The apparatus of claim 1, further comprising an adjustment structure for allowing the X-ray detector to be moved further way from the X-ray beam emitter.

3. The apparatus of claim 1, further comprising a second X-ray apparatus located on the opposite side of the conveyor from the first X-ray apparatus and having an X-ray beam emitter mounted at a first position adjacent said conveying path for emitting an X-ray beam passing through said container as it is conveyed along said conveying path to a second detector located opposite the second X-ray apparatus.

4. The apparatus as in Claim 3, wherein the first X-ray apparatus and the second X-ray apparatus are adapted to each provide at least two X-ray beams to two detectors.

5. The apparatus as in Claim 4, wherein the at least two beams of the first X-ray apparatus and the at least two beams of the second X-ray apparatus are positioned 450 apart.
6. The apparatus as in Claim 1, wherein said detector’s position can be selectively adjusted toward and away from said conveying path as well as along a line parallel to said conveying path.

7. The apparatus as in Claim 1, wherein there is only one beam emitter and one detector for the conveying path.

8. A method for the non-destructive inspection of material housed in having an inwardly protruding crown on a bottom wall thereof, said method comprising:
   - conveying the containers along a conveying path;
   - passing at least one X-ray beam through said container as it is conveyed along said conveying path;
   - receiving a portion of the at least one X-ray beam passed through said container; and
   - generating a signal representative of the portion of the at least one X-ray beam and therefore of an image representative of said material;
   wherein a portion of said at least one X-ray beam is directed along a path that substantially parallels a sloping surface of the inwardly protruding crown.

9. The method as in Claim 8, wherein the at least one X-ray comprises a first and a second X-ray beam.

10. The method as in Claim 8, wherein the at least one X-ray comprises a first, second, third, and fourth X-ray beam.

11. The method as in Claim 10, further comprising the step of placing the first and second X-ray beams substantially at a 450 angle with respect to each other and placing the third and fourth X-ray beams substantially at a 450 angle with respect to each other.

12. The method as in Claim 8, further comprising allowing the X-ray detector to be moved further way from the X-ray beam emitter.
13. An apparatus for non-destructively inspecting materials housed in a container having a inwardly protruding crown on a bottom wall thereof and adapted to travel along a conveying path, said apparatus comprising:
   a first x-ray apparatus having a first X-ray beam emitter mounted at a first x-ray position adjacent the conveying path for emitting an X-ray beam passing through the container;
   a first detector assembly mounted adjacent said conveying path on a side of said conveying path opposite that of said first x-ray apparatus for receiving a portion of the X-ray beam that has passed through the container;
   a second x-ray apparatus having a second x-ray beam emitter for emitting an X-ray beam passing through the container mounted at a first x-ray position adjacent the conveying path and substantially opposite the first x-ray apparatus; and
   a second detector assembly mounted adjacent said conveying path on a side of said conveying path opposite that of said second x-ray apparatus for receiving a portion of the X-ray beam that has passed through the container;
   wherein the first and second X-ray apparatus are positioned to direct a portion of the respective X-ray at an angle along a path that substantially parallels the slope of the crown.

14. The apparatus as in Claim 13, wherein the angle formed by the X-ray beams of the first X-ray beam emitter and the second X-ray beam emitter is about 450°.

15. The apparatus as in Claim 13, wherein the angle formed by the X-ray beams of the third X-ray beam emitter and the fourth X-ray beam emitter is about 450°.

16. The apparatus as in Claim 13, wherein the first detector and the second detector’s position can be selectively adjusted toward and away from said conveying path as well as along a line parallel to said conveying path.
17. The apparatus as in Claim 13, wherein the first detector assembly comprises at least two detectors.

18. The apparatus as in Claim 13, wherein the second detector assembly comprises at least two detectors.

19. The apparatus as in Claim 13, wherein the first x-ray apparatus comprises a dual beam generator.

20. The apparatus as in Claim 13, wherein the second x-ray apparatus comprises a dual beam generator.