

We claim:

1. A method of analyzing an article comprising the steps of:

scanning the article with a structured light system to obtain 3-dimensional information relating to the article;

processing the article 3-dimensional information to determine the minimum number of scans necessary to scan the surface of the article;

directing a laser beam at a surface of the article to create ultrasonic surface displacements, wherein the laser beam is directed at the surface of the article according to processed 3-dimensional information;

detecting the ultrasonic surface displacements;

correlating article 3-dimension information with the ultrasonic surface displacements;

processing the ultrasonic surface displacement data; and

correlating the 3-dimensional information and the processed ultrasonic surface displacements to provide coordinate measurements for the ultrasonic surface displacement data.

2. The method of claim 1 further comprising positioning the article for evaluation.

3. The method of claim 1 wherein the article comprises a composite material.

4. The method of claim 1 wherein scanning the article with a structured light system comprises:

providing an structured light apparatus comprising a camera, a light beam producing element and means for moving structured light apparatus;

projecting a light beam onto the surface of the article;

operating the camera to receive the image of the light beam being projected onto the surface of the article; and

moving the structured light apparatus to a next location until the entire surface of the article has been measured.

5. The method of claim 1 wherein the steps for detecting ultrasonic surface displacements at the surface of the article comprise:

generating a detection laser beam;

directing the detection laser beam at the surface of the article;

scattering the detection laser beam with the ultrasonic surface displacement of the article to produce phase modulated light;

processing the phase modulated light to obtain data relating to the ultrasonic surface displacements at the surface; and

collecting the data to provide information about the structure of the article.

6. The method of claim 1 wherein the known data set is CAD data.

7. The method of claim 1 further comprising calibrating the structured light system prior to measuring the dimensions of the article.

8. The method of claim 1 wherein the article is an aircraft part.

9. The method of claim 1 wherein the article is an aircraft.

10. The method of claim 1 further comprising executing a first computer implemented process to process the light detected from the article.

11. The method of claim 10 further comprising executing a second computer implemented process to obtain 3-dimensional information relating to the shape of the article.

12. The method of claim 10 further comprising executing a third computer implemented process to process the 3-dimensional information relating to the article and determine the minimum number of scans necessary to evaluate the article.

13. A method of evaluating aircraft parts in service comprising:

scanning an as-made aircraft part with a structured light system to obtain article 3-dimensional information;

processing the article 3-dimensional information to determine the minimum number of scans necessary to scan the surface of the as-made aircraft part;

directing a laser beam at a surface of the as-made aircraft part to create ultrasonic surface displacements, wherein the laser beam is directed at the surface of the article according to processed 3-dimensional information to minimize the number of scans necessary to scan the surface of the as-made aircraft part;

detecting the ultrasonic surface displacements;

correlating the as-made aircraft part 3-dimensional information with the ultrasonic surface displacements;

comparing the as-made aircraft part 3-dimensional information with a known data set;

processing the ultrasonic surface displacement data;

correlating the known data set and the processed ultrasonic surface displacements to provide coordinate measurements for the ultrasonic surface displacement data of the as-made aircraft part;

storing the as-made aircraft part 3-dimensional information and the ultrasonic surface displacement data;

installing the as-made aircraft part onto an aircraft;

scanning the installed aircraft part with a structured light system to obtain article 3-dimensional information;

processing the article 3-dimensional information to determine the minimum number of scans necessary to scan the surface of the installed aircraft part;

directing a laser beam at a surface of the installed aircraft part to create ultrasonic surface displacements, wherein the laser beam is directed at the surface of the article according to processed 3-dimensional information to minimize the number of scans necessary to scan the surface of the as-made aircraft part;

directing a laser beam at a surface of the installed aircraft part to create ultrasonic surface displacements;

detecting the ultrasonic surface displacements;

correlating the installed aircraft part 3-dimensional information with the ultrasonic surface displacements;

processing the ultrasonic surface displacement data;

correlating the known data set and the processed ultrasonic surface displacements to provide coordinate measurements for the ultrasonic surface displacement data; and

comparing the installed aircraft part 3-dimensional information and processed ultrasonic surface displacement data and the as-made aircraft part 3-dimensional information and processed ultrasonic surface displacement data.

14. The method of claim 13 wherein the evaluation of the aircraft part includes the identification of a defect selected from the group consisting of delamination, cracks, inclusions, disbands, and combinations thereof.

We claim:

1. A method of analyzing an article with a laser ultrasound system, the method comprising the steps of:

a. scanning the article with a structured light system to obtain 3-dimensional information relating to the article;

b. capturing a full image of the article with a texture camera to obtain an actual image of the article;

c. generating a 3-dimensional view of the article using the 3-dimensional information;

d. determining a minimum number of laser ultrasound poses required to analyze an entire surface of the article based on the 3-dimensional view and the actual image of the article;

e. directing a laser beam from the laser ultrasound system at a surface of the article to create ultrasonic surface displacements according to the poses of step (d); and

f. detecting the ultrasonic surface displacements to provide ultrasonic surface displacement data.

2. The method of claim 1 wherein scanning the article with the structured light system comprises generating a series of point clouds, each corresponding to the shape of the article from a specific view, then merging the point clouds to assemble a composite point cloud of the entire article.

3. The method of claim 1 wherein the step of scanning the article with a structured light system further comprises the steps of:

providing a structured light apparatus comprising a camera, a light beam producing element and means for moving structured light apparatus;

projecting the light beam from the light beam producing element onto the surface of the article;

operating the camera to receive the image of the light beam being projected onto the surface of the article; and

moving the structured light apparatus to a next location until the entire surface of the article has been scanned.

4. The method of claim 1 wherein the steps for detecting ultrasonic surface displacements at the surface of the article comprise:

generating a detection laser beam;

directing the detection laser beam at the surface of the article;

scattering the detection laser beam with the ultrasonic surface displacement of the article to produce phase modulated light;

processing the phase modulated light to obtain data relating to the ultrasonic surface displacements at the surface; and

collecting the data to provide information about the structure of the article.

5. The method of claim 1 further comprising comparing the actual image of the article with the 3-dimensional information relating to the article and computer aided design data of the article.

6. The method of claim 3 wherein scanning the article with a structured light system comprises executing a first computer implemented process to process the light beam projected onto the article and received by the camera.

7. The method of claim 6 further comprising executing a second computer implemented process to obtain 3-dimensional information relating to the shape of the article.

8. The method of claim 7 further comprising executing a third computer implemented process to process the 3-dimensional information relating to the article and determine the minimum number of scans necessary for the laser ultrasound system to scan the entire surface of the article.

9. A method of evaluating aircraft parts in service with a laser ultrasound system, comprising:

scanning an as-made aircraft part with a structured light system to obtain article 3-dimensional information;

capturing an actual image of the aircraft part with a texture camera;

directing a laser beam from the laser ultrasound system at a surface of the as-made aircraft part to create ultrasonic surface displacements;

minimizing the number of scans necessary to scan the entire surface of the as-made aircraft part based on the 3-dimensional information and the actual image obtained from the texture camera;

detecting the ultrasonic surface displacements created by the laser beam;

correlating the as-made aircraft part 3-dimensional information with the detected ultrasonic surface displacements to provide correlated ultrasonic surface displacement data;

processing the correlated ultrasonic surface displacement data;

storing the as-made aircraft part 3-dimensional information and the ultrasonic surface displacement data;

installing the as-made aircraft part onto an aircraft;

scanning the installed aircraft part with a structured light system to obtain article 3-dimensional information of the installed aircraft part;

processing the article 3-dimensional information of the installed aircraft part and determining the minimum number of scans necessary for the laser ultrasonic system to scan the entire surface of the installed aircraft part;

directing the laser beam from the laser ultrasonic system at a surface of the installed aircraft part to create ultrasonic surface displacements, wherein the laser beam of the laser ultrasonic system is directed at the surface of the installed aircraft part according to processed 3-dimensional information of the installed aircraft part to minimize the number of scans necessary for the laser ultrasonic system to scan the surface of the installed aircraft part;

detecting the ultrasonic surface displacements in the installed aircraft part created by the laser beam of the laser ultrasonic system;

correlating the installed aircraft part 3-dimensional information with the detected ultrasonic surface displacements of the installed aircraft part to provide correlated ultrasonic surface displacement data for the installed aircraft part;

processing the correlated ultrasonic surface displacement data;

correlating the known data set and the processed correlated ultrasonic surface displacements of the installed aircraft part to provide coordinate measurements for the ultrasonic surface displacement data of the installed aircraft part; and

evaluating the condition of the installed aircraft part by comparing the installed aircraft part 3-dimensional information and processed correlated ultrasonic surface displacement data and the as-made aircraft part 3-dimensional information and processed correlated ultrasonic surface displacement data.

10. The method of claim 9 wherein the evaluation of the aircraft part includes the identification of a defect selected from the group consisting of delamination, cracks, inclusions, disbands, and combinations thereof.

11. The method of claim 3, wherein the camera is a CCD camera.

12. The method of claim 1, wherein the laser beam directed at the surface of the article to create ultrasonic surface displacements is a mid-IR laser.

13. The method of claim 1, further comprising processing the article 3-dimensional information and determining the minimum number of scans necessary for the laser ultrasonic system to scan the entire surface of the article.

14. The method of claim 1, further comprising varying an optical wavelength of the laser beam such that an absorption band of the surface of the article is observed over a wavelength range of the laser beam.

15. The method of claim 9, further comprising varying an optical wavelength of the laser beam such that an absorption band of the surface of the as-made aircraft part and/or the installed aircraft part is observed over a wavelength range of the laser beam.

16. A method of analyzing an article substantially as herein described with reference to any one of the embodiments of the invention illustrated in the accompanying drawings and/or examples.

17. A method of evaluating aircraft parts in service with a laser ultrasound system substantially as herein described with reference to any one of the embodiments of the invention illustrated in the accompanying drawings and/or examples.