After the different layers have been laid up on the tool, the layers consolidated and cured upon exposure to temperature and pressure, thus forming the final composite structure. Thereafter, the composite structure may be inspected to determine whether inconsistencies are present. The inspection may be performed using x-ray inspection systems, ultrasound inspection systems, and other types of non-destructive inspection systems.

If an inconsistency is identified, the composite structure may be reworked. In some cases, the inconsistency may result in the composite structure being discarded, requiring new composite structure to be manufactured. Examples of inconsistencies that may be present in a composite structure include voids, porosity, delamination, foreign object debris (FOD), and other types of inconsistencies.

Reworking parts or discarding and remanufacturing composite structures may delay the completion of an aircraft using the composite structures. Further, reworking or discarding parts may increase the cost in manufacturing aircraft by an undesirable amount.

Therefore, it would be desirable to have a method and apparatus that takes into account at least one of the issues discussed above as well as possibly other issues.

SUMMARY

In one illustrative embodiment, a method for inspecting a composite workpiece is present. A response to electromagnetic radiation directed to a surface of the composite workpiece is separated into a number of wavelengths for each of a number of locations on the surface of the composite workpiece. A set of contaminants not visible to a naked eye on the surface of the composite workpiece is identified from the number of wavelengths for the each of the number of locations. A two-dimensional image of the surface of the composite workpiece is generated with a set of graphical indicators indicating the set of contaminants identified from the number of wavelengths for the each of the number of locations on the surface of the composite workpiece.

In another illustrative embodiment, a method for inspecting a tool for laying up layers of composite material is present. A response to electromagnetic radiation directed to a surface of the tool is separated into a number of wavelengths for each of a number of locations on the surface of the tool prior to laying up the layers of

composite material on the surface of the tool. A set of contaminants is identified from the number of wavelengths for the each of the number of locations on the surface of the tool. A two-dimensional image of the surface of the tool is generated with a set of graphical indicators indicating the set of contaminants identified from the number of wavelengths for the each of the number of locations on the surface of the tool.

In still another illustrative embodiment, a method for inspecting a composite material is present. A response to infrared electromagnetic radiation directed to a surface of the composite material is separated into a number of infrared wavelengths for each of a number of locations on the surface of the composite material. A set of inconsistencies for the composite material is identified from the number of infrared wavelengths for the each of the number of locations. A two-dimensional image of the composite material with a set of graphical indicators indicating the set of inconsistencies identified from the number of infrared wavelengths for the each of the number of locations on the surface of the composite material is generated.

In yet another illustrative embodiment, an apparatus comprises a spectral sensor system and an analyzer. The spectral sensor system is configured to separate a response to electromagnetic radiation directed at a surface of a composite workpiece into a number of wavelengths comprising wavelengths outside of a visible light spectrum and generate data from the number of wavelengths of the electromagnetic radiation. The analyzer is configured to cause the spectral sensor system to generate the data from the response after a number of layers of composite material have been laid up for the composite workpiece and prior to the number of layers of composite material being cured. The analyzer is further configured to generate a two-dimensional image of the surface of the composite workpiece with a set of graphical indicators indicating a set of contaminants identified from the number of wavelengths for each of a number of locations on the surface of the composite workpiece.

The features and functions can be achieved independently in various embodiments of the present disclosure or may be combined in yet other embodiments in which further details can be seen with reference to the following description and drawings.

CLAIMS:

What is claimed is:

1. A method for inspecting a composite workpiece (206), the method comprising:

separating a response (228) to electromagnetic radiation (224) directed to a surface (212) of the composite workpiece (206) into a number of wavelengths (230) for each of a number of locations (226) on the surface (212) of the composite workpiece (206);

identifying a set of contaminants (210) on the surface (212) of the composite workpiece (206) from the number of wavelengths (230) for the each of the number of locations (226); and

generating a two-dimensional image (236) of the surface (212) of the composite workpiece (206) with a set of graphical indicators (242) indicating the set of contaminants (210) identified from the number of wavelengths (230) for the each of the number of locations (226) on the surface (212) of the composite workpiece (206).

2. The method of claim 1, wherein identifying the set of contaminants (210) on the surface (212) of the composite workpiece (206) from the number of wavelengths (230) for the each of the number of locations (226) comprises:

identifying the set of contaminants (210) based on a comparison of the number of wavelengths (230) for the each of the number of locations (226) on the surface (212) of the composite workpiece (206) to a data (232)base of wavelengths for known contaminants.

3. The method of claim 1 further comprising:

projecting the two-dimensional image (236) with the set of graphical indicators (242) onto the surface (212) of the composite workpiece (206).

4. The method of claim 1, wherein generating the two-dimensional image (236) of the surface (212) of the composite workpiece (206) with the set of graphical indicators (242) indicating the set of contaminants (210) identified from the number of wavelengths (230) for the each of the number of locations (226) on the surface (212) of the composite workpiece (206) comprises:

generating the two-dimensional image (236) of the surface (212) of the composite workpiece (206) with a visible light sensor system (302); and

including the set of graphical indicators (242) indicating the set of contaminants (210) identified from the number of wavelengths (230) for the each of the number of locations (226) on the surface (212) of the composite workpiece (206) in the two-dimensional image (236) in locations corresponding to the number of locations (226).

5. The method of claim 1, wherein the composite workpiece (206) comprises:

a number of layers of composite material.

6. The method of claim 1, wherein the separating, identifying, and generating steps are performed when a number of layers of composite material are laid up for the composite workpiece (206).

7. The method of claim 6, wherein the separating, identifying, and generating steps are performed each time the number of layers of the composite material are laid up for the composite workpiece (206) prior to curing the number of layers of composite material.

8. The method of claim 1, wherein the separating, identifying, and generating steps are performed prior to curing the composite workpiece (206).

9. The method of claim 1, wherein separating the response (228) to the electromagnetic radiation (224) directed to the surface (212) of the composite workpiece (206) into the number of wavelengths (230) for the each of the number of locations (226) on the surface (212) of the composite workpiece (206) comprises:

scanning the response (228) to the electromagnetic radiation (224) across a filter (310), wherein the filter (310) is configured to separate the response (228) into the number of wavelengths (230).

10. The method of claim 9, wherein the filter (310) is an interference filter (314).

11. The method of claim 1, wherein the electromagnetic radiation (224) is generated

by at least one of a laser system, a halogen light system, a light emitting diode system, a xenon arc lamp system, a laser diode system, a tunable laser system, and a quartz lamp system.

12. The method of claim 1, wherein the composite workpiece (206) forms a part for a platform (220) selected from one of a mobile platform, a stationary platform, a land-based structure, an aquatic-based structure, a space-based structure, a surface ship, a tank, a personnel carrier, a train, a spacecraft, a space station, a satellite, a submarine, an automobile, a power plant, a bridge, a dam, a manufacturing facility, and a building.

13. A method for inspecting a tool (204) for laying up layers of composite material, the method comprising:

separating a response (228) to electromagnetic radiation (224) directed to a surface (212) of the tool (204) into a number of wavelengths (230) for each of a number of locations (226) on the surface (212) of the tool (204) prior to laying up the layers of composite material on the surface (212) of the tool (204);

identifying a set of contaminants (210) from the number of wavelengths (230) for the each of the number of locations (226) on the surface (212) of the tool (204); and

generating a two-dimensional image (236) of the surface (212) of the tool (204) with a set of graphical indicators (242) indicating the set of contaminants (210) identified from the number of wavelengths (230) for the each of the number of locations (226) on the surface (212) of the tool (204).

14. A method for inspecting a composite material, the method comprising:

separating a response (228) to electromagnetic radiation (224) directed to a surface (212) of the composite material into a number of wavelengths (230) for each of a number of locations (226) on the surface (212) of the composite material;

identifying a set of inconsistencies for the composite material from the number of wavelengths (230) for the each of the number of locations (226); and

generating a two-dimensional image (236) of the composite material with a set of graphical indicators (242) indicating the set of inconsistencies identified from the number of wavelengths (230) for the each of the number of locations (226) on the surface (212) of the composite material.

15. The method of claim 14, wherein the composite material is selected from one of a layer of composite material in a composite workpiece (206) and the layer of composite material prior to being used to form the composite workpiece (206).

16. An apparatus comprising:

a spectral sensor system (300) configured to separate a response (228) to electromagnetic radiation (224) directed at a surface (212) of a composite workpiece (206) into a number of wavelengths (230) and generate data (232) from the number of wavelengths (230) of the electromagnetic radiation (224); and

an analyzer (222) configured to cause the spectral sensor system (300) to generate the data (232) from the response (228) after a number of layers of composite material have been laid up for the composite workpiece (206) and prior to the number of layers of composite material being cured, and to generate a two-dimensional image (236) of the surface (212) of the composite workpiece (206) with a set of graphical indicators (242) indicating a set of contaminants (210) identified from the number of wavelengths (230) for each of a number of locations (226) on the surface (212) of the composite workpiece (206).

17. The apparatus of claim 16 further comprising:

a visible light sensor system (302) configured to generate a visible light image of the surface (212) of the composite workpiece (206), and wherein the analyzer (222) is configured to include the set of graphical indicators (242) indicating the set of contaminants (210) identified from the number of wavelengths (230) for the each of the number of locations (226) on the surface (212) of the composite workpiece (206) in the visible light image in locations corresponding to the number of locations (226) to form the two-dimensional image (236) of the surface (212) of the composite workpiece (206) with the set of graphical indicators (242) indicating the set of contaminants (210) identified from the number of wavelengths (230) for the each of the number of locations (226) on the surface (212) of the composite workpiece (206).

18. The apparatus of claim 16 further comprising:

an electromagnetic radiation source (218) configured to generate the electromagnetic radiation (224).

19. The apparatus of claim 16, wherein the spectral sensor system (300) comprises:

a filter (310) configured to separate the response (228) to the electromagnetic radiation (224) directed at the surface (212) of the composite workpiece (206) into the number of wavelengths (230); and

a sensor array (312) configured to generate the data (232) from the number of wavelengths (230) of the electromagnetic radiation (224) separated in the response (228) by the filter (310).

20. The apparatus of claim 16, wherein the composite workpiece (206) is for a composite aircraft part.

CLAIMS:

What is claimed is:

1. A method for inspecting a composite workpiece, the method comprising:

separating a response to electromagnetic radiation directed to a surface of the composite workpiece into a number of wavelengths for each of a number of locations on the surface of the composite workpiece;

identifying a set of contaminants not visible to a naked eye on the surface of the composite workpiece from the number of wavelengths for the each of the number of locations; and

generating a two-dimensional image of the surface of the composite workpiece with a set of graphical indicators indicating the set of contaminants not visible to the naked eye identified from the number of wavelengths for the each of the number of locations on the surface of the composite workpiece.

2. The method of claim 1, wherein identifying the set of contaminants not visible to the naked eye on the surface of the composite workpiece from the number of wavelengths for the each of the number of locations comprises:

identifying the set of contaminants not visible to the naked eye based on a comparison of the number of wavelengths for the each of the number of locations on the surface of the composite workpiece to a database of wavelengths for known contaminants.

3. The method of claim 1 further comprising:

projecting the two-dimensional image with the set of graphical indicators onto the surface of the composite workpiece.

4. The method of claim 1, wherein generating the two-dimensional image of the surface of the composite workpiece with the set of graphical indicators indicating the set of contaminants not visible to the naked eye identified from the number of wavelengths for the each of the number of locations on the surface of the composite workpiece comprises:

generating the two-dimensional image of the surface of the composite workpiece with a visible light sensor system; and

including the set of graphical indicators indicating the set of contaminants not visible to the naked eye identified from the number of wavelengths for the each of the number of locations on

the surface of the composite workpiece in the two-dimensional image in locations corresponding to the number of locations.

5. The method of claim 1, wherein the separating, identifying, and generating steps are performed when a number of layers of composite material are laid up for the composite workpiece.

6. The method of claim 5, wherein the separating, identifying, and generating steps are performed each time the number of layers of the composite material are laid up for the composite workpiece prior to curing the number of layers of composite material.

7. The method of claim 1, wherein the separating, identifying, and generating steps are performed prior to curing the composite workpiece.

8. The method of claim 1, wherein separating the response to the electromagnetic radiation directed to the surface of the composite workpiece into the number of wavelengths for the each of the number of locations on the surface of the composite workpiece comprises:

scanning the response to the electromagnetic radiation across a filter, wherein the filter is configured to separate the response into the number of wavelengths and the filter is selected from the group consisting of an optical prism, a holographic grating, a conventional grating, and a wedge filter.

9. The method of claim 8, wherein the filter is the wedge filter and further comprises a length defining frequencies configured to be passed by the wedge filter, wherein the frequencies increase in a direction along the length.

10. The method of claim 1, wherein the electromagnetic radiation is generated by at least one of a halogen light system, a light emitting diode system, a xenon arc lamp system, a laser diode system, and a quartz lamp system.

11. The method of claim 1, wherein the composite workpiece forms a part for a platform selected from one of an aquatic-based structure, a space-based structure, a surface ship, a tank, a train, a spacecraft, a space station, a satellite, a submarine, an automobile, a power plant, a bridge, a dam, a manufacturing facility, and a building.

12. A method for inspecting a tool for laying up layers of composite material, the method comprising:

separating a response to electromagnetic radiation directed to a surface of the tool into a number of wavelengths for each of a number of locations on the surface of the tool prior to laying up the layers of composite material on the surface of the tool;

identifying a set of contaminants from the number of wavelengths for the each of the number of locations on the surface of the tool; and

generating a two-dimensional image of the surface of the tool with a set of graphical indicators indicating the set of contaminants identified from the number of wavelengths for the each of the number of locations on the surface of the tool.

13. A method for inspecting a composite material, the method comprising:

separating a response to infrared electromagnetic radiation directed to a surface of the composite material into a number of infrared wavelengths for each of a number of locations on the surface of the composite material;

identifying a set of inconsistencies for the composite material from the number of infrared wavelengths for the each of the number of locations; and

generating a two-dimensional image of the composite material with a set of graphical indicators indicating the set of inconsistencies identified from the number of infrared wavelengths for the each of the number of locations on the surface of the composite material.

14. The method of claim 13, wherein the set of inconsistencies comprises inconsistencies selected from the group consisting of voids and a porosity.

15. An apparatus comprising:

a spectral sensor system configured to separate a response to electromagnetic radiation directed at a surface of a composite workpiece into a number of wavelengths comprising wavelengths outside of a visible light spectrum and generate data from the number of wavelengths of the electromagnetic radiation; and

an analyzer configured to cause the spectral sensor system to generate the data from the response after a number of layers of composite material have been laid up for the composite workpiece and prior to the number of layers of composite material being cured, and to generate a two-dimensional image of the surface of the composite workpiece with a set of graphical indicators indicating a set of contaminants identified from the number of wavelengths for each of a number of locations on the surface of the composite workpiece.

16. The apparatus of claim 15 further comprising:

a visible light sensor system configured to generate a visible light image of the surface of the composite workpiece, and wherein the analyzer is configured to include the set of graphical indicators indicating the set of contaminants identified from the number of wavelengths for the each of the number of locations on the surface of the composite workpiece in the visible light image in locations corresponding to the number of locations to form the two-dimensional image of the surface of the composite workpiece with the set of graphical indicators indicating the set of contaminants identified from the number of wavelengths for the each of the number of locations on the surface of the composite workpiece.

17. The apparatus of claim 15, wherein the spectral sensor system comprises:

a filter configured to separate the response to the electromagnetic radiation directed at the surface of the composite workpiece into the number of wavelengths comprising the wavelengths outside of the visible light spectrum;

a sensor array comprising sensors configured to generate the data from the number of wavelengths comprising the wavelengths outside of the visible light spectrum of the electromagnetic radiation separated in the response by the filter, wherein the sensors are selected from the group consisting of digital-charged-coupled-devices, complimentary metal oxide semiconductor devices, indium antimonide (InSb) semiconductor devices, and mercury cadmium telluride (HgCdTe) semiconductor devices; and

wherein the number of wavelengths comprises a continuous range of wavelengths.

18. The apparatus of claim 17 further comprising:

a director system comprising a moveable mirror system configured to cause the response to the electromagnetic radiation to be scanned across the filter; and

an electromagnetic radiation source configured to generate the electromagnetic radiation and to pass coherent light through the moveable mirror system toward the surface of the composite workpiece.

19. The apparatus of claim 15, wherein the set of contaminants identified from the number of wavelengths for the each of the number of locations on the surface of the composite workpiece comprises contaminants selected from the group consisting of liquids, moisture, and plastic particles.

20. The apparatus of claim 15, wherein the analyzer is further configured to identify the set of contaminants by comparing the data to a signature database, wherein a signature in the signature database comprises an intensity for a wavelength in the number of wavelengths that is unique to a contaminant in the set of contaminants and wherein the data comprises at least one of intensities for the number of wavelengths, amplitudes for the number of wavelengths, and the wavelengths.