CLAIMS

l. A system for inspecting a surface of a structure for defects comprising:

an inspection apparatus including a heating device for heating a section of the surface of the structure, an infrared camera for receiving infrared radiation from the surface in response to heating, a controller configured to generate thermographs from the received infrared radiation, and a communication device;

a training system including an expert system module configured to determine correlations between a set of thermographs, the thermographs generated by a thermal simulation of modeled structural elements with defects, and parameters of the modeled structural elements; and

a computer system communicatively coupled to the training system and the inspection apparatus, the computer system adapted to receive thermographs received from the inspection apparatus and to detect quantitative parameters of defects in the structure using the correlations obtained from the training system,

wherein the training system further includes an optimized acquisition parameter module configured to automatically determine acquisition parameters for controlling the inspection apparatus based on material properties of the structure, environmental conditions, and a thermal analysis of a modeled structural element.

2. The system of claim 1, wherein the structure is composed of a composite material.

3. The system of claim 1, wherein the quantitative parameters detected by the computer system include a location, a depth, an orientation, a defect type and an entrapped media type.

4. The system of claim 1, wherein the training system further includes a defect microstructure database module configured to generate the set of modeled structural elements, each structural element including an integrated defect.

5. The system of claim 4, wherein the training system further includes a virtual thermograph database module configured to perform a thermal analysis of each of the modeled structural elements and to generate transient thermographs corresponding to the structural elements.

6. The system of claim 5, wherein the thermal analysis is performed using finite element analysis.

7. The system of claim 1, wherein parameters of each modeled structural element includes a location, defect type, defect size, defect orientation and entrapped media.

8. The system of claim 7, wherein the defect type is one of delamination, unique void, matrix cracking, fiber-matrix de-bonding, multiple voids, and holes.

9. The system of claim 7, wherein the entrapped media is liquid or gas selected for inspection.

10. The system of claim 1, wherein the acquisition parameters determined by the optimized acquisition parameter module include a heating mode, heating time and target heat flux level for operating the heating device, and an acquisition time for operating the infrared camera of the inspection apparatus.

11. The system of claim 1, wherein the thermal analysis is performed on a modeled structural element having at least one of a smallest and a deepest defect.

12. The system of claim 1, wherein the computer system receives the acquisition parameters from the training system and transmits the acquisition parameters to the inspection apparatus.

13. The system of claim 1, wherein the expert system module employs a neural network to determine the correlations between the set of thermographs and the corresponding set of modeled structural elements.

14. The system of claim 1, wherein the inspection apparatus includes a clamp element for fixing the apparatus to the surface of the structure and a chassis unit for housing the heating element and infrared camera.

15. The system of claim 15, wherein the chassis unit is slidingly coupled to the clamp element and rotatable circumferentially with respect to the surface of the structure.

16. The system of claim 15, wherein the chassis unit and clamp element are coupled to rotatable and translatable wheels enabling the inspection apparatus to rotate circumferentially and translate longitudinally along the surface of the structure.

17. A system for inspecting a surface of a structure for defects comprising:

an inspection apparatus including a heating device for heating a section of the surface of the structure, an infrared camera for receiving infrared radiation from the surface in response to heating, a controller configured to generate thermographs from the received infrared radiation, and a communication device;

a training system including an expert system module configured to determine correlations between a set of thermographs and parameters of modeled structural elements, and an optimized acquisition parameter module configured to automatically determine parameters for controlling the inspection apparatus based on material properties of the structure and environmental conditions; and

a computer system communicatively coupled to the training system and the inspection apparatus, the computer system adapted to receive thermographs received from the inspection apparatus and to detect quantitative parameters of defects in the structure using the correlations obtained from the training system;

wherein the quantitative parameters including an entrapped media type.

18. A method of training a system to enable an inspection apparatus to perform an accurate quantitative inspection of a surface of a structure for defects, the method comprising:

receiving operator inputs concerning properties of the structure and environmental conditions at the structure;

generating a set of structural elements using the operator inputs, each of the modeled structural elements including an integrated defect;

generating thermographs corresponding to each of the structural elements through application of a transient thermal analysis;

computing correlations between the thermographs and the parameters of corresponding structural elements; and

determining optimal acquisition parameters for controlling the inspection apparatus based on material properties of the structure, environmental conditions, and a thermal analysis of a structural element,

wherein the correlations enable thermographs taken of structures to be analyzed to determine quantitative parameters of defects in the structure.

19.The method of claim 19, wherein the structure is composed of a composite material.

20. The method of claim 19, wherein the transient thermal analysis employs finite element analysis.

21. The method of claim 19, wherein the structural elements are characterized by a location, defect type, defect size, defect orientation and entrapped media.

22. The method of claim 22, wherein the defect type is one of delamination, unique void, matrix cracking, fiber-matrix de-bonding, multiple voids, and holes.

23. The system of claim 22, wherein the entrapped media is a liquid or gas selected for inspection.

24. The method of claim 19, wherein the acquisition parameters include a heating parameters including at least one of a heating mode, a heating time and a target heat flux level and an acquisition time for operating the inspection apparatus.

25. The method of claim 19, wherein the thermal analysis is performed on a structural element having the smallest and a deepest defect.

26. The method of claim 19, wherein the correlations between the thermographs and the parameters of corresponding structural elements are determined using a machine learning technique.

27. The method of claim 28, wherein the machine learning technique employs a neural network.

28. A method of quantitatively inspecting a surface of a structure for defects from which infrared thermographs are acquired by an inspection apparatus, the method comprising:

obtaining a set of correlations between parameters of modeled structural defects and simulated thermographs of the modeled structural defects, and optimal acquisition parameters for configuring the inspection apparatus for acquiring thermograph data from the structure;

communicating the acquisition parameters to the inspection apparatus;

receiving infrared thermograph data acquired from the structure from the inspection apparatus;

analyzing the received thermograph data using the obtained correlations; and

determining parameters of defects within the structure based on the analysis of the received thermograph.

29. The method of claim 30, wherein acquisition parameters are communicated to the inspection apparatus and thermograph data is received from the inspection apparatus via wireless communication.

30. The method of claim 30, wherein the parameters of defects within the structure determined include a location, a depth, a defect type and an entrapped media type.

31. The method of claim 30, wherein the acquisition parameters for configuration of the inspection apparatus include heating parameters including at least one of a heating mode, a heating time and a target heat flux level for applying heat to the structure and an acquisition time detecting infrared radiation from the structure.

32. The method of claim 30, wherein the optimal acquisition parameters are determined based on a material of the structure and environmental conditions at the structure.

33. A method of quantitatively inspecting a surface of a structure using an inspection apparatus having a heating device and an infrared camera, the method comprising:

receiving optimal acquisition parameters for configuring the heating element and the heating a portion of the surface of the structure;

heating a section of the structure using the heating device according to the received acquisition parameters;

detecting infrared radiation emitted from the section of the structure according to the received acquisition parameters

generating thermograph data from the detected infrared radiation; and

communicating the thermograph data to a computer system to determine defects of the structure using the thermograph data;

wherein the analysis employs a set of correlations between parameters of modeled structural defects and simulated thermographs of the modeled structural defects and obtains parameters of corresponding to the received thermograph data using the correlations

34. The method of claim 35, further comprising removably fixing the inspection apparatus in proximity to the structure using a clamp element.

35. The method of claim 36, further comprising rotating the heating device and infrared camera of the inspection apparatus circumferentially around the structure with respect to the clamp element.

36. The method of claim 37, further comprising translating the clamp element longitudinally over the structure using at least one wheel.

37. The method of claim 35, wherein the acquisition parameters include a heating time and target heat flux level for heating the section of the structure and an acquisition time detecting infrared radiation from the structure.

38. The method of claim 35, wherein the optimal acquisition parameters are determined based on a material of the structure and environmental conditions at the structure.