[0004] Because NITI allows for the non-destructive testing and monitoring of an object or system whenever thermal signals are present, NITI may be utilized in many diverse applications. In cases where sufficient thermal signals are not present, they can be generated at the object or system surface.

SUMMARY

[0004a] In an aspect, the present disclosure refers to a system for non-invasive sensing of an object having a volume with a surface and an internal region, comprising: a non-invasive sensor including: a heat flux sensor having one or more heat flux sensor output terminals; a temperature sensor having one or more temperature sensor output terminals, wherein the non-invasive sensor is adapted to be placed on or near the surface of the object, where the internal region of the object has internal properties indicated by corresponding internal parameter(s) and an internal temperature distribution. The heat flux sensor is arranged to produce a voltage that is related to heat transfer leaving or entering the object at the surface by a calibration constant, a sensitivity constant, a calibration curve, or a sensitivity curve associated with the heat flux sensor. Circuitry, coupled to the one or more heat flux sensor output terminals and the one or more temperature sensor output terminals, to: receive a measured temperature signal from the temperature sensor at one or more specified times; receive a measured heat flux signal from the heat flux sensor at one or more specified times; determine an estimated indicative quantity for one or more of the internal properties at one or more specified times based on at least the measured temperature signal and the measured heat flux signal; and generate information indicating one or more of the estimated indicative quantit(ies) determined for the internal propert(ies) of the object at one or more specified times.

[0004b] In another aspect, the present disclosure refers to a system for non-invasive sensing of an object having a volume with a surface and an internal region, comprising: a first non-invasive, heat flux sensor-temperature sensor pair; a second non-invasive, heat flux sensor-temperature sensor pair; each of the first and second non-invasive, heat flux sensor-temperature sensor pairs including: a heat flux sensor having one or more

heat flux sensor output terminals; a temperature sensor having one or more temperature sensor output terminals, wherein the first and second non-invasive, heat flux sensor-temperature sensor pairs are adapted to be placed at different locations on or near the surface of the object and are subject to a differential heat flux environment, and where the internal region of the object has internal properties indicated by corresponding internal parameter(s) and an internal temperature distribution, circuitry, coupled to the one or more heat flux sensor output terminals and the one or more temperature sensor output terminals of each of the first and second non-invasive, heat flux sensor-temperature sensor pairs, and configured to: receive a first measured temperature signal from the temperature sensor in the first non-invasive, heat flux sensor-temperature sensor pair at one or more specified times; receive a first measured heat flux signal from the heat flux sensor in the first non-invasive, heat flux sensor-temperature sensor pair at one or more specified times; receive a second measured temperature signal from the temperature sensor in the second non-invasive, heat flux sensor-temperature sensor pair at one or more specified times; receive a second measured heat flux signal from the heat flux sensor in the second non-invasive, heat flux sensor-temperature sensor pair at one or more specified times; determine an estimated indicative quantity for one or more of the internal properties of the object at one or more specified times based on at least the measured temperature signals from the temperature sensors in the first and second non-invasive, heat flux sensor-temperature sensor pairs at one or more specified times and the measured heat flux signals from the heat flux sensors in the first and second non-invasive, heat flux sensor-temperature sensor pairs at one or more specified times; and generate information indicating one or more of the estimated indicative quantit(ies) determined for the internal propert(ies) of the object at one or more specified times.

[0004c] In another aspect, the present disclosure refers to a non-invasive sensor adapted to be placed on or near a surface of an object having a volume with a surface and an internal region, where the internal region of the object has internal properties indicated by corresponding internal parameter(s) and an internal temperature distribution, the non-invasive sensor comprising: a non-invasive, heat flux sensor-temperature sensor pair; the non-invasive, heat flux sensor-temperature sensor pair including: a heat flux

sensor having one or more heat flux sensor output terminals to provide a measured heat flux signal for a location on or near the surface of the object, and a temperature sensor having one or more temperature sensor output terminals to provide a measured temperature signal for a location on or near the surface of the object, wherein the non-invasive sensor is configured such that a mismatch does not exist between the measured heat flux signal and the measured temperature signal.

[0004d] In another aspect, the present disclosure refers to a non-invasive sensor adapted to be placed on or near a surface of an object having a volume with a surface and an internal region, where the internal region of the object has internal properties indicated by corresponding internal parameter(s) and an internal temperature distribution, the non-invasive sensor comprising: a first non-invasive, heat flux sensor-temperature sensor pair; a second non-invasive, heat flux sensor-temperature sensor pair; each of the first and second non-invasive, heat flux sensor-temperature sensor pairs including: a heat flux sensor having one or more heat flux sensor output terminals; a temperature sensor having one or more temperature sensor output terminals, wherein the first and second non-invasive, heat flux sensor-temperature sensor pairs are adapted to be placed at different locations on or near the surface of the object and are subject to a differential heat flux environment.

[0005] At least some examples provide a system for non-invasive sensing of an object having a volume with a surface and an internal region. The system comprises a non-invasive sensor including: a heat flux sensor having one or more heat flux sensor output terminals, and a temperature sensor having one or more temperature sensor output terminals. The non-invasive sensor may be placed on or near the surface of the object. The internal region of the object has internal properties indicated by corresponding internal parameters and an internal temperature distribution. Control circuitry, coupled to the one or more heat flux sensor output terminals and the one or more temperature sensor output terminals, is adapted to: receive a measured temperature signal from the temperature sensor at one or more specified times; receive a measured heat flux signal from the heat flux sensor at the one or more specified times; determine a measure of heat

transfer leaving or entering the object at the surface based on the measured heat flux signal at the one or more specified times; determine a value for each of the internal parameters at the one or more specified times; determine an internal temperature distribution of the internal region of the object at the one or more specified times based on the measured temperature signal, the measured heat flux signal, and the values of the internal parameters; and generate information indicating the internal temperature distribution of the internal region of the object at the one or more specified times.

[0006] At least some examples provide a system for non-invasive sensing of an object having a volume with a surface and an internal region. The system includes a non-invasive sensor including: a heat flux sensor having one or more heat flux sensor output terminals, and a temperature sensor having one or more temperature sensor output terminals. The non-invasive sensor is adapted to be placed on or near the surface of the object, and the internal region of the object has internal properties indicated by corresponding internal parameters and an internal temperature distribution. Control

Claims

1. A system for non-invasive sensing of an object having a volume with a surface and an internal region, comprising:

a non-invasive sensor including:

a heat flux sensor having one or more heat flux sensor output terminals;

a temperature sensor having one or more temperature sensor output terminals,

wherein the non-invasive sensor is adapted to be placed on or near the surface of the object, where the internal region of the object has internal properties indicated by corresponding internal parameter(s) and an internal temperature distribution,

wherein the heat flux sensor is arranged to produce a voltage that is related to heat transfer leaving or entering the object at the surface by a calibration constant, a sensitivity constant, a calibration curve, or a sensitivity curve associated with the heat flux sensor, and

circuitry, coupled to the one or more heat flux sensor output terminals and the one or more temperature sensor output terminals, to:

receive a measured temperature signal from the temperature sensor at one or more specified times;

receive a measured heat flux signal from the heat flux sensor at one or more specified times;

determine an estimated indicative quantity for one or more of the internal properties at one or more specified times based on at least the measured temperature signal and the measured heat flux signal; and

generate information indicating one or more of the estimated indicative quantit(ies) determined for the internal propert(ies) of the object at one or more specified times.

2. The system of claim 1, wherein the circuitry is configured to:

determine a calculated sensor temperature at one or more specified times based on at least the measured temperature signal, the measured heat flux signal, one or more of the estimated internal property indicative quantit(ies); and

compare the calculated sensor temperature with a measured temperature that is based on the measured temperature signal to determine a difference.

3. The system of claim 2, wherein the circuitry is configured to adjust the estimated indicative quantit(ies) for one or more of the internal properties to reduce the difference, and

wherein when the difference is less than a threshold amount or otherwise determined to be minimal, the estimated indicative quantit(ies) for the internal propert(ies) are deemed to be optimally updated and the circuitry is configured to generate information indicating the optimally updated estimated indicative quantit(ies) for the internal propert(ies).

4. A system for non-invasive sensing of an object having a volume with a surface and an internal region, comprising:

a first non-invasive, heat flux sensor-temperature sensor pair;

a second non-invasive, heat flux sensor-temperature sensor pair;

each of the first and second non-invasive, heat flux sensor-temperature sensor pairs including:

a heat flux sensor having one or more heat flux sensor output terminals;

a temperature sensor having one or more temperature sensor output terminals,

wherein the first and second non-invasive, heat flux sensor-temperature sensor pairs are adapted to be placed at different locations on or near the surface of the object and are subject to a differential heat flux environment, and where the internal region of the object has internal properties indicated by corresponding internal parameter(s) and an internal temperature distribution,

circuitry, coupled to the one or more heat flux sensor output terminals and the one or more temperature sensor output terminals of each of the first and second non-invasive, heat flux sensor-temperature sensor pairs, and configured to:

receive a first measured temperature signal from the temperature sensor in the first non-invasive, heat flux sensor-temperature sensor pair at one or more specified times;

receive a first measured heat flux signal from the heat flux sensor in the first non-invasive, heat flux sensor-temperature sensor pair at one or more specified times;

receive a second measured temperature signal from the temperature sensor in the second non-invasive, heat flux sensor-temperature sensor pair at one or more specified times;

receive a second measured heat flux signal from the heat flux sensor in the second non-invasive, heat flux sensor-temperature sensor pair at one or more specified times;

determine an estimated indicative quantity for one or more of the internal properties of the object at one or more specified times based on at least the measured temperature signals from the temperature sensors in the first and second non-invasive, heat flux sensor-temperature sensor pairs at one or more specified times and the measured heat flux signals from the heat flux sensors in the first and second non-invasive, heat flux sensor-temperature sensor pairs at one or more specified times; and

generate information indicating one or more of the estimated indicative quantit(ies) determined for the internal propert(ies) of the object at one or more specified times.

5. The system of any of claims 1 to 4, wherein the circuitry is configured to use an estimated initial indicative quantity for one or more of the internal properties at specified times(s) and/or a predetermined initial indicative quantity for one or more of the internal properties at specified times(s).

6. The system of any of claims 1 to 5, wherein the circuitry is configured to include one or more effects associated with an estimated thermal contact resistance between the temperature sensor(s) and the surface of the object.

7. The system of any of claims 1 to 6, wherein the circuitry is configured to:

determine the estimated indicative quantit(ies) for one or more of the internal properties at one or more specified times based on at least the measured temperature signal(s), the measured heat flux signal(s), and indicative quantit(ies) determined for one or more of the internal properties.

8. The system of any of claims 1 to 7, further comprising one or more non-NITI based devices, wherein the circuitry is configured to utilize one or more output signals of the one or more non-NITI based devices to determine the estimated indicative quantit(ies) for one or more of the internal properties.

9. A non-invasive sensor adapted to be placed on or near a surface of an object having a volume with a surface and an internal region, where the internal region of the

object has internal properties indicated by corresponding internal parameter(s) and an internal temperature distribution, the non-invasive sensor comprising:

a non-invasive, heat flux sensor-temperature sensor pair;

the non-invasive, heat flux sensor-temperature sensor pair including:

a heat flux sensor having one or more heat flux sensor output terminals to provide a measured heat flux signal for a location on or near the surface of the object, and

a temperature sensor having one or more temperature sensor output terminals to provide a measured temperature signal for a location on or near the surface of the object,

wherein the non-invasive sensor is configured such that a mismatch does not exist between the measured heat flux signal and the measured temperature signal.

10. A non-invasive sensor adapted to be placed on or near a surface of an object having a volume with a surface and an internal region, where the internal region of the object has internal properties indicated by corresponding internal parameter(s) and an internal temperature distribution, the non-invasive sensor comprising:

a first non-invasive, heat flux sensor-temperature sensor pair;

a second non-invasive, heat flux sensor-temperature sensor pair;

each of the first and second non-invasive, heat flux sensor-temperature sensor pairs including:

a heat flux sensor having one or more heat flux sensor output terminals;

a temperature sensor having one or more temperature sensor output terminals,

wherein the first and second non-invasive, heat flux sensor-temperature sensor pairs are adapted to be placed at different locations on or near the surface of the object and are subject to a differential heat flux environment.

11. The non-invasive sensor of claim 9 or claim 10, comprising one or more non-NITI based devices to provide one or more output signals for utilization in determining estimated indicative quantit(ies) for one or more of the internal properties.

12. The system of any of claims 1 to 8 or the non-invasive sensor of any of claims 9 to 11, wherein the heat flux sensor(s) are based on differential thermopile technology, thin-film technology, or one or more thermoelectric devices.

13. The system of any of claims 1 to 8 or the non-invasive sensor of any of claims 9 to 12, wherein the heat flux sensor(s) include two or more thermocouple junctions

connected in series to provide a voltage output that is indicative of a temperature difference across a given thermal resistance.

14. The system of any of claims 1 to 8 or the non-invasive sensor of any of claims 9 to 13, wherein the temperature sensor(s) are based on thermocouple, fiber optic, semiconductor, or thermistor technology.

15. The system in any of claims 1 to 8 or the non-invasive sensor of any of claims 9 to 14, further comprising one or more external thermal devices for heating and/or cooling the non-invasive sensor, the first non-invasive, heat flux sensor-temperature sensor pair, or the second non-invasive, heat flux sensor-temperature sensor pair.

16. The system or non-invasive sensor of claim 15, wherein the one or more external thermal devices are configured for heating and/or cooling such that a measured heat flux signal and/or a measured temperature signal is obtained.

17. The non-invasive sensor of any of claims 9 to 16, wherein the non-invasive sensor is useable in a system configured to determine one or more of the internal properties of the internal region of the object.

18. The non-invasive sensor of any of claims 9 to 17 including multiple heat flux sensors and/or multiple temperature sensors.