solved by currently available techniques. Accordingly, the subject matter of the present application has been developed to provide apparatuses, systems, and methods for detecting kissing bonds in bonded joints of parts that may overcome at least some of the above-discussed shortcomings of prior art techniques.

According to an aspect, there is provided a method of detecting kissing bonds in a bonded joint of a part, the method comprising determining the intensity, of an electromagnetic shockwave, sufficient to induce a separation of a kissing bond in a target portion of the bonded joint by: generating test electromagnetic shockwaves through a target portion of a bonded joint of a test part; incrementally increasing an intensity of each one of the test electromagnetic shockwaves while monitoring the test part for visual signs of anomalies; measuring a temperature of the test part after each incremental increase in the intensity of the test electromagnetic shockwaves; and waiting to generate a subsequent one of the test electromagnetic shockwaves until after the temperature of the test part is at or below a predetermined threshold temperature; wherein the intensity of the test electromagnetic shockwave just prior to the test electromagnetic shockwave that results in a visual sign of anomalies is selected as the intensity of the electromagnetic shockwave sufficient to induce a separation of the kissing bond; generating an electromagnetic shockwave through a target portion of the bonded joint by discharging a slow capacitor bank of an electromagnetic shockwave generator into a coil of the electromagnetic shockwave generator and then a fast capacitor bank of the electromagnetic shockwave generator into the coil in the opposite direction to create a differential magnetic field from the coil to a back of the bonded joint, wherein the electromagnetic shockwave has the selected intensity sufficient to induce a separation of the kissing bond in the target portion of the bonded joint and insufficient to induce a separation of a healthy bond, adjacent the kissing bond, in the target portion; and in response to generating the electromagnetic shockwave through the target portion of the bonded joint: generating a transmitted ultrasonic pulse; directing the transmitted ultrasonic pulse into the target portion of the bonded joint; and receiving a received ultrasonic pulse from the target portion of the bonded joint.

The following is a non-exhaustive list of examples, which may or may not be claimed, of the subject matter, disclosed herein.

Disclosed herein is a detection assembly for detecting kissing bonds in a bonded joint of a part. The detection assembly comprises an electromagnetic shockwave generator that is configured to generate an electromagnetic shockwave through a target portion of the bonded joint. The electromagnetic shockwave has an intensity sufficient to induce a separation of a kissing bond in the target portion of the bonded joint and insufficient to induce a separation of a healthy bond, adjacent the kissing bond, in the target portion. The detection assembly also comprises an ultrasonic sensor that is configured to generate a transmitted ultrasonic pulse, direct the transmitted ultrasonic pulse into the target portion of the bonded joint, and receive a received ultrasonic pulse from the target portion of the bonded joint in response to the electromagnetic shockwave generator generating the electromagnetic shockwave through the target portion of the bonded joint. The preceding subject matter of this paragraph characterizes example 1 of the present disclosure.

The detection assembly is movable along the part. The preceding subject matter of this paragraph characterizes example 2 of the present disclosure, wherein example 2 also includes the subject matter according to example 1, above.

The electromagnetic shockwave generator and the ultrasonic sensor are non-movably fixed relative to each other. The preceding subject matter of this paragraph characterizes example 3 of the present disclosure, wherein example 3 also includes the subject matter according to example 2, above.

The ultrasonic sensor is integrated into the electromagnetic shockwave generator. The preceding subject matter of this paragraph characterizes example 4 of the present disclosure, wherein example 4 also includes the subject matter according to example 3, above.

CLAIMS

1. A method of detecting kissing bonds in a bonded joint of a part, the method comprising:

determining the intensity, of an electromagnetic shockwave, sufficient to induce a separation of a kissing bond in a target portion of the bonded joint by:

generating test electromagnetic shockwaves through a target portion of a bonded joint of a test part;

incrementally increasing an intensity of each one of the test electromagnetic shockwaves while monitoring the test part for visual signs of anomalies;

measuring a temperature of the test part after each incremental increase in the intensity of the test electromagnetic shockwaves; and

waiting to generate a subsequent one of the test electromagnetic shockwaves until after the temperature of the test part is at or below a predetermined threshold temperature;

wherein the intensity of the test electromagnetic shockwave just prior to the test electromagnetic shockwave that results in a visual sign of anomalies is selected as the intensity of the electromagnetic shockwave sufficient to induce a separation of the kissing bond;

generating an electromagnetic shockwave through a target portion of the bonded joint by discharging a slow capacitor bank of an electromagnetic shockwave generator into a coil of the electromagnetic shockwave generator and then a fast capacitor bank of the electromagnetic shockwave generator into the coil in the opposite direction to create a differential magnetic field from the coil to a back of the bonded joint, wherein the electromagnetic shockwave has the selected intensity sufficient to induce a separation of the kissing bond in the target portion of the bonded joint and insufficient to induce a separation of a healthy bond, adjacent the kissing bond, in the target portion; and

in response to generating the electromagnetic shockwave through the target portion of the bonded joint:

generating a transmitted ultrasonic pulse;

directing the transmitted ultrasonic pulse into the target portion of the bonded joint; and

receiving a received ultrasonic pulse from the target portion of the bonded joint.

2. The method according to claim 1, further comprising:

identifying at least one characteristic of the received ultrasonic pulse;

performing a comparison between the at least one characteristic of the received ultrasonic pulse and at least one predetermined characteristic; and

determining a presence or absence of a kissing bond in the target portion of the bonded joint based on the comparison.

3. The method according to claim 2, wherein:

the at least one characteristic of the received ultrasonic pulse comprises a measured signal response of the received ultrasonic pulse;

the at least one predetermined characteristic comprises a predetermined signal response;

the absence of a kissing bond is determined when the measured signal response is equal to the predetermined signal response; and

the presence of a kissing bond is determined when the measured signal response is not equal to the predetermined signal response.

4. The method according to any preceding claim, wherein the part is made of an electrically-conductive material.

5. The method according to any preceding claim, wherein:

the electromagnetic shockwave is generated by an electromagnetic shockwave generator; and

the electromagnetic shockwave generator is in direct contact with the part when the electromagnetic shockwave generator generates the electromagnetic shockwave and when the transmitted ultrasonic pulse is generated, the transmitted ultrasonic pulse is directed into the target portion of the bonded joint, and the received ultrasonic pulse is received from the target portion of the bonded joint.

6. The method according to any preceding claim, wherein:

the bonded joint of the part comprises a first layer bonded to a second layer by a bond;

the bond within the target portion of the bonded joint comprises the kissing bond;

the electromagnetic shockwave separates the first layer from the second layer at the kissing bond to form a void between the first layer and the second layer; and

while the first layer and the second layer are separated by the electromagnetic shockwave, at least a portion of the transmitted ultrasonic pulse reflects off of the void to form the received ultrasonic pulse.

7. The method according to any preceding claim, wherein the predetermined threshold temperature is 50° C.

8. The method according to any preceding claim, wherein determining the intensity, of the electromagnetic shockwave, sufficient to induce a separation of a kissing bond in the target portion of the bonded joint further comprises inspecting the test part for structural anomalies.

9. The method according to claim 8, wherein inspecting the test part for structural anomalies comprises a tensile test and/or a compression test.

10. The method according to any preceding claim, wherein:

the electromagnetic shockwave is generated by an electromagnetic shockwave generator;

the transmitted ultrasonic pulse is generated by an ultrasonic sensor;

the transmitted ultrasonic pulse is directed by the ultrasonic sensor;

the received ultrasonic pulse is received by the ultrasonic sensor; and

the method further comprises co-moving the electromagnetic shockwave generator and the ultrasonic sensor into a position in which the electromagnetic shockwave directly contacts the target portion of the bonded joint.

11. The method according to any preceding claim, wherein the test part replicates the part.

12. The method according to any preceding claim, wherein the selected intensity is below an intensity associated with a predetermined tensile force resistance limit of a healthy bond.

13. The method according to claim 12, wherein the predetermined tensile force resistance limit of a healthy bond is the maximum tensile force the healthy bond is capable of withstanding before breaking down and separating.

14. The method according to claim 2, wherein:

the at least one characteristic of the received ultrasonic pulse includes a measured signal response of the received ultrasonic pulse, the measured signal response including one or more of a measured frequency, a measured amplitude, and a measured phase of the received ultrasonic pulse; and

the at least one predetermined characteristic includes a predetermined signal response, the predetermined signal response being one or more of a predetermined frequency, a predetermined amplitude, and a predetermined phase.

15. The method of any preceding claim, wherein the electromagnetic shockwave is a tension pulse in the part, generated by inducing eddy currents in the part.