the interpretation of testing results requires substantial expertise due to the fact that complex multiple factors could contribute to the change of ultrasonic waves.

[0005] Eddy-current based SHM method detects the change of eddy-current induced by electromagnetic induction for electrically conductive structures under test. It is limited mostly to metallic structures and is not applicable to electrically non-conducting structures. Furthermore, the detection of eddy-current is limited to the surface, due to the shielding of the magnetic field by the surface layer.

[0006] Radiography-based SHM method images the internal defects of the structures by transmitting X-ray or γ-ray through the structures under test. However, due to the safety concerns of radioactivity, it cannot be used to do on-site testing in most cases. Moreover, some structures are not accessible on both sides, preventing the transmission testing geometry of radiography.

[0007] Optical interferometry, such as holography and shearography, images the surface displacement or displacement gradient by lasers when the structures under test are under loading and non-loading conditions. As the optical method is sensitive to surface changes, the detection depth is generally very limited using conventional loading methods.

[0008] A need therefore exists to provide structural health monitoring methods and systems that can address at least some of the limitations of the conventional techniques, or provide a useful alternative.

SUMMARY

[0009] An aspect of the present disclosure provides a structural health monitoring method comprising:

directly forming an acoustic transducer on a surface of a structure to be monitored;

generating, by the acoustic transducer, an acoustic wave to apply stress loading to a region of interest on the structure; and

detecting a presence of a defect in the region of interest, wherein detecting comprises a non-contact optical imaging of the region of interest with and without the stress loading and an analysis of imaging data from the non-contact optical imaging,

wherein directly forming the acoustic transducer comprises:

directly forming a piezoelectric layer on the surface of the structure;

patterning a plurality of electrodes on the piezoelectric layer; and

selecting a periodicity of the electrodes based on a wavelength of the acoustic wave; and

wherein directly forming the piezoelectric layer on the surface of the structure comprises depositing a piezoelectric ceramic layer on the surface of the structure by a thermal spray process.

[0010] ~~Directly forming the acoustic transducer may comprise:~~

~~directly forming a piezoelectric layer on the surface of the structure;~~

~~patterning a plurality of electrodes on the piezoelectric layer; and~~

~~selecting a periodicity of the electrodes based on a wavelength of the acoustic wave.~~

[0011] The method may further comprise forming the plurality of electrodes as concentric curves, and selecting a center of the concentric curves to coincide with the region of interest.

[0012] The transducer may comprise a phased-array transducer comprising a plurality of elements, and generating the acoustic wave may comprise controlling a time delay between the elements to tune a penetration depth of the acoustic wave in the region of interest.

[0013] Generating the acoustic wave may further comprise activating selected elements of the plurality of elements.

[0014] The method may further comprise directly forming a plurality of acoustic transducers on the surface of the structure and simultaneously generating a plurality of acoustic waves corresponding to the acoustic transducers to detect the presence of one or more defects.

[0015] ~~Directly forming the piezoelectric layer on the surface of the structure may comprise depositing a piezoelectric ceramic layer on the surface of the structure by a thermal spray process.~~

[0016] ~~Directly forming the piezoelectric layer on the surface of the structure may comprise depositing a piezoelectric polymer layer on the surface of the structure by an aerosol spray process.~~

[0017] The non-contact optical imaging of the structure may comprise shearography imaging.

[0018] The non-contact optical imaging of the structure may comprise holographic imaging.

[0019] The non-contact optical imaging of the structure may comprise optical metrology.

[0020] Another aspect of the present disclosure provides a structural health monitoring system comprising:

an acoustic transducer formed directly on a surface of a structure to be monitored;

a non-contact optical imaging device configured to image a region of interest on the structure; and

a processor communicatively coupled to the acoustic transducer and the non-contact optical imaging device,

wherein the acoustic transducer is configured to generate an acoustic wave to apply stress loading to the region of interest, and wherein the processor is configured to receive imaging data of the region of interest from the non-contact optical imaging device with and without the stress loading and to analyse the imaging data to detect a presence of a defect in the region of interest,

wherein the acoustic transducer comprises a piezoelectric layer and a plurality of electrodes patterned on the piezoelectric layer, and wherein a periodicity of the electrodes is selected based on a wavelength of the acoustic wave; and

wherein the piezoelectric layer comprises a piezoelectric ceramic layer thermally sprayed on the surface of the structure.

[0021] ~~The acoustic transducer may comprise a piezoelectric layer and a plurality of electrodes patterned on the piezoelectric layer, and a periodicity of the electrodes may be selected based on a wavelength of the acoustic wave.~~

[0022] The plurality of electrodes may comprise concentric curves, and a center of the concentric curves may be selected to coincide with the region of interest.

[0023] The transducer may comprise a phased-array transducer comprising a plurality of elements, and the processor may be further configured to control a time delay between the elements to tune a penetration depth of the acoustic wave in the region of interest.

[0024] The processor may be further configured to activate selected elements of the plurality of elements to generate the acoustic wave.

[0025] The system may comprise a plurality of acoustic transducers directly formed on the surface of the structure and communicatively coupled to the processor, and the plurality of acoustic transducers may be configured to simultaneously generate a plurality of acoustic waves to detect the presence of one or more defects.

[0026] ~~The piezoelectric layer may comprise a piezoelectric ceramic layer.~~

[0027] ~~The piezoelectric layer may comprise a piezoelectric polymer layer.~~

CLAIMS

1. A structural health monitoring method comprising:

directly forming an acoustic transducer on a surface of a structure to be monitored;

generating, by the acoustic transducer, an acoustic wave to apply stress loading to a region of interest on the structure; and

detecting a presence of a defect in the region of interest, wherein detecting comprises a non-contact optical imaging of the region of interest with and without the stress loading and an analysis of imaging data from the non-contact optical imaging.

wherein directly forming the acoustic transducer comprises:

directly forming a piezoelectric layer on the surface of the structure;

patterning a plurality of electrodes on the piezoelectric layer; and

selecting a periodicity of the electrodes based on a wavelength of the acoustic wave; and

wherein directly forming the piezoelectric layer on the surface of the structure comprises depositing a piezoelectric ceramic layer on the surface of the structure by a thermal spray process.

~~2. The method as claimed in claim 1, wherein directly forming the acoustic transducer comprises:~~

~~directly forming a piezoelectric layer on the surface of the structure;~~

~~patterning a plurality of electrodes on the piezoelectric layer; and~~

~~selecting a periodicity of the electrodes based on a wavelength of the acoustic wave.~~

~~3~~2. The method as claimed in claim ~~2~~1, further comprising forming the plurality of electrodes as concentric curves, and selecting a center of the concentric curves to coincide with the region of interest.

~~4~~3. The method as claimed in ~~any one of the preceding claims~~claim 1 or 2, wherein the transducer comprises a phased-array transducer comprising a plurality of elements, and wherein generating the acoustic wave comprises controlling a time delay between the elements to tune a penetration depth of the acoustic wave in the region of interest.

~~5~~4. The method as claimed in claim ~~4~~3, wherein generating the acoustic wave further comprises activating selected elements of the plurality of elements.

~~6~~5. The method as claimed in any one of the preceding claims, further comprising directly forming a plurality of acoustic transducers on the surface of the structure and simultaneously generating a plurality of acoustic waves corresponding to the acoustic transducers to detect the presence of one or more defects.

~~7. The method as claimed in any one of claims 2 to 6, wherein directly forming the piezoelectric layer on the surface of the structure comprises depositing a piezoelectric ceramic layer on the surface of the structure by a thermal spray process.~~

~~8. The method as claimed in any one of claims 2 to 6, wherein directly forming the piezoelectric layer on the surface of the structure comprises depositing a piezoelectric polymer layer on the surface of the structure by an aerosol spray process.~~

~~9~~6. The method as claimed in any one of the preceding claims, wherein the non-contact optical imaging of the structure comprises shearography imaging.

~~10~~7. The method as claimed in any one of claims 1 to ~~8~~5, wherein the non-contact optical imaging of the structure comprises holographic imaging.

~~11~~8. The method as claimed in any one of claims 1 to ~~8~~5, wherein the non-contact optical imaging of the structure comprises optical metrology.

~~12~~9. A structural health monitoring system comprising:

an acoustic transducer formed directly on a surface of a structure to be monitored;

a non-contact optical imaging device configured to image a region of interest on the structure; and

a processor communicatively coupled to the acoustic transducer and the non-contact optical imaging device,

wherein the acoustic transducer is configured to generate an acoustic wave to apply stress loading to the region of interest, and wherein the processor is configured to receive imaging data of the region of interest from the non-contact optical imaging device with and without the stress loading and to analyse the imaging data to detect a presence of a defect in the region of interest:

wherein the acoustic transducer comprises a piezoelectric layer and a plurality of electrodes patterned on the piezoelectric layer, and wherein a periodicity of the electrodes is selected based on a wavelength of the acoustic wave; and

wherein the piezoelectric layer comprises a piezoelectric ceramic layer thermally sprayed on the surface of the structure.

~~13. The system as claimed in claim 12, wherein the acoustic transducer comprises a piezoelectric layer and a plurality of electrodes patterned on the piezoelectric layer, and wherein a periodicity of the electrodes is selected based on a wavelength of the acoustic wave.~~

~~14~~10. The system as claimed in claim ~~13~~9, wherein the plurality of electrodes comprise concentric curves, and wherein a center of the concentric curves is selected to coincide with the region of interest.

~~15~~11. The system as claimed in ~~any one of claims 12 to 14~~claim 9 or 10, wherein the transducer comprises a phased-array transducer comprising a plurality of elements, and wherein the processor is further configured to control a time delay between the elements to tune a penetration depth of the acoustic wave in the region of interest.

~~16~~12. The system as claimed in claim ~~15~~11, wherein the processor is further configured to activate selected elements of the plurality of elements to generate the acoustic wave.

~~17~~13. The system as claimed in any one of claims ~~12 to 16~~9 to 12, comprising a plurality of acoustic transducers directly formed on the surface of the structure and communicatively coupled to the processor, wherein the plurality of acoustic transducers are configured to simultaneously generate a plurality of acoustic waves to detect the presence of one or more defects.

~~18. The system as claimed in any one of claims 12 to 17, wherein the piezoelectric layer comprises a piezoelectric ceramic layer.~~

~~19. The system as claimed in any one of claims 12 to 17, wherein the piezoelectric layer comprises a piezoelectric polymer layer.~~

~~20~~14. The system as claimed in any one of claims ~~12 to 19~~9 to 13, wherein the non-contact optical imaging device comprises a shearography imaging device.

~~21~~15. The system as claimed in any one of claims ~~12 to 19~~9 to 13, wherein the non-contact optical imaging device comprises a holographic imaging device.

~~22~~16. The system as claimed in any one of claims ~~12 to 19~~9 to 13, wherein the non-contact optical imaging device comprises an optical metrology device.