(19) DANMARK

(10) DK/EP 3516261 T3

Patent- og Varemærkestyrelsen

(12) Oversættelse af europæisk patentskrift

(51) Int.Cl.: *F 16 F 9/30 (2006.01)* *B 32 B 7/12 (2006.01)* *B 32 B 15/04 (2006.01)*
B 32 B 15/06 (2006.01) *B 32 B 15/20 (2006.01)* *B 32 B 25/04 (2006.01)*
B 32 B 25/16 (2006.01) *B 32 B 25/18 (2006.01)* *B 32 B 25/20 (2006.01)*
B 32 B 27/40 (2006.01) *C 09 J 7/28 (2018.01)* *C 09 J 7/29 (2018.01)*

(45) Oversættelsen bekendtgjort den: **2023-03-06**

(80) Dato for Den Europæiske Patentmyndigheds bekendtgørelse om meddelelse af patentet: **2022-12-07**

(86) Europæisk ansøgning nr.: **17778065.7**

(86) Europæisk indleveringsdag: **2017-09-20**

(87) Den europæiske ansøgnings publiceringsdag: **2019-07-31**

(86) International ansøgning nr.: **US2017052419**

(87) Internationalt publikationsnr.: **WO2018057570**

(30) Prioritet: **2016-09-20 US 201662397073 P**

(84) Designerede stater: **AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**

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(54) Benævnelse: **Flerlagsbånd**

(56) Fremdragne publikationer:
US-A- 2 819 032
US-A- 3 160 549
US-A- 3 476 209
US-A- 5 851 327

DESCRIPTION

[0001] The present subject matter relates to tapes, including adhesive tapes, for damping vibration.

[0002] Vibration damping adhesive tapes are well known in the art. However, in order to achieve desired vibration damping characteristics, most such adhesive tapes are relatively thick, utilize large amounts of adhesive, and/or significantly add to the overall weight of the system or assembly undergoing vibration. Accordingly, a need remains for adhesive tapes that effectively dampen or reduce vibration and which are relatively thin and/or lightweight. US 3 160 549 A discloses vibration damping structures. US 2 819 032 A discloses aircraft fuselage having a panel damping material.

[0003] The difficulties and drawbacks associated with previous approaches are addressed in the present subject matter as follows. The subject matter according to the present invention is defined in the claims.

[0004] In one aspect, the present subject matter provides a tape for damping vibration. The tape comprises a substrate defining a first face and an oppositely directed second face. The tape also comprises a first layer of viscoelastic damping material at least partially disposed on the first face of the substrate. The tape additionally comprises a second layer of viscoelastic damping material at least partially disposed on the second face of the substrate. The substrate has a thickness within a range of from about 5 μm to about 3,000 μm, and each of the layers of viscoelastic damping materials has a thickness within a range of from about 2 μm to about 5,000 μm.

[0005] In another aspect, the present subject matter provides a constrained layer system comprising at least one of a first component and a second component (also referred to as a surface) undergoing vibration. The first component and/or second component may be comprised of any material requiring damping, including but not limited to, metals, plastics, and wood. The tape described herein is at least partially disposed between the first component and the second component. The system also comprises a vibration damping tape including (i) a substrate defining a first face and an oppositely directed second face, (ii) a first layer of viscoelastic damping material at least partially disposed on the first face of the substrate, and (iii) a second layer of viscoelastic damping material at least partially disposed on the second face of the substrate. The substrate has a thickness within a range of from about 5 μm to about 3,000 μm, and each of the viscoelastic damping material layers has a thickness within a range of from about 2 μm to about 5,000 μm. At least one of the first layer of viscoelastic damping material and the second layer of viscoelastic damping material is adhered to at least one of the first component and the second component.

[0006] As will be realized, the subject matter described herein is capable of other and different embodiments and its several details are capable of modifications in various respects, all

without departing from the claimed subject matter. Accordingly, the drawings and description are to be regarded as illustrative and not restrictive.

Figure 1 is a schematic cross sectional view of an embodiment of a viscoelastic damping material laminate or tape in accordance with the present subject matter.

Figure 2 is a schematic cross sectional view of another embodiment of a viscoelastic damping material laminate or tape in accordance with the present subject matter.

Figures 3 and 4 are schematic cross sectional views of constrained layer systems using the tapes of Figure 1.

Figure 5 is a schematic cross sectional view of a constrained layer system using the tapes of Figure 2.

Figure 6 is a graph of composite loss factor as a function of temperature for a tape in accordance with the present subject matter as compared to two prior art tapes.

Figure 7 is a graph of composite loss factor as a function of temperature for a tape in accordance with the present subject matter as compared to two prior art tapes.

Figure 8 is a graph of a linear-density normalized damping efficiency index for a tape in accordance with the present subject matter as compared to commercially available tapes.

[0007] The present subject matter provides viscoelastic damping material laminates (which may also be referred to herein as tapes) which exhibit relatively high vibration damping characteristics, which may be described as damping efficiency as described herein. In particular versions of the tapes, the tapes are relatively thin and/or lightweight as compared to many currently known vibration damping tapes. The viscoelastic damping material laminates are provided in a variety of configurations including a single substrate configuration and a multilayer configuration utilizing two or more substrates. Each configuration includes at least two (2) layers of viscoelastic damping material and optional release liners at least partially disposed on the viscoelastic damping material face(s). In some embodiments, the tape may include additional viscoelastic damping layers. In one embodiment, the tape may include at least three (3) layers of both viscoelastic damping material and substrate at least partially disposed on the surface of viscoelastic damping material face(s). In some embodiments, the tape may include at least four (4) layers of both viscoelastic damping material and substrate at least partially disposed on the surface of viscoelastic damping material face(s). In some embodiments, the tape may include at least five (5) layers of both viscoelastic damping material and substrate at least partially disposed on the surface of viscoelastic damping material face(s). In some embodiments, the tape may include at least six (6) layers of both viscoelastic damping material and substrate at least partially disposed on the surface of viscoelastic damping material face(s). Although many embodiments described herein refer to a first and second layer of viscoelastic damping materials, any additional layers may also have these embodiments. In still other embodiments, the viscoelastic damping material(s) can

exhibit at least one compositional gradient or region such as along the viscoelastic damping material thickness.

[0008] In some embodiments, compositional gradients or regions may provide a gradual change in material properties from one surface to another surface of the viscoelastic damping material(s). The additional viscoelastic damping layers may be disposed upon each other or disposed on at least one substrate. The present subject matter also provides constrained layer systems utilizing the viscoelastic damping material laminates.

Substrates

[0009] The tapes of the present subject matter utilize one or more substrates. Although specific embodiments of a single substrate tape and a dual substrate tape are described herein, it will be understood that the present subject matter tapes include tapes having additional substrates, including three substrates, four substrates, five substrates, and six or more substrates. The additional substrates may be disposed upon each other or disposed on at least one viscoelastic damping layer. In some embodiments, the substrates may be multi-layer and at least partially disposed on each other. In tapes utilizing a plurality of substrates, typically a layer of viscoelastic damping material is at least partially disposed between adjacent substrates. For example, in one embodiment of the present subject matter, a tape is provided comprising five substrates in which a layer of viscoelastic damping material is at least partially disposed between adjacent substrates, and a fifth layer of viscoelastic damping material is at least partially disposed along a face of one of the outermost substrates.

[0010] The substrates used in the viscoelastic damping material laminates of the present subject matter are relatively thin, i.e., have a thickness within a range of from about 5 μm to about 3,000 μm, in many embodiments from about 10 μm to about 500 μm, and in certain embodiments have a thickness of about 125 μm or about 250 μm. In some embodiments, the substrates have a range of room temperature Young's Modulus of about 1 GPa to about 1000 GPa, in other embodiments from about 20 GPa to about 500 GPa, and in certain embodiments from about 40 GPa to about 200 GPa. In some embodiments, the substrate is a metal foil that may have a room temperature Young's Modulus of at least 20GPa.

[0011] In many embodiments, the substrates may be comprised of or are in the form of a metal foil. In some embodiments, there may be more than one substrate metal foil (which may be referred to as a first metal foil, a second metal foil, a third metal foil, etc.). Generally, any metal foil (including a first metal foil, a second metal foil, a third metal foil, etc.) can be used, including ferrous and nonferrous based foils. A wide array of metals can be used such as, but not limited to, Aluminum, Copper, Tin, Brass, Gold, Silver, Nickel, Steel, Stainless Steel, mixtures and/or alloys of these with other metals and/or agents. In many embodiments, an Aluminum foil is used. However, it is contemplated that other metals and/or combinations of metals may be used including Columbium/Niobium, Hafnium, Iridium, Molybdenum and alloys, Rhenium and alloys, Tantalum, Tungsten and alloys, Platinum, Platinum and Iridium, Alloy 42

and 52, Hastelloy, Inconel, Invar 36®, Kovar®, Monel, Nichrome/Tophet "A," Phosphor Bronze, Titanium, Vanadium, Zirconium, and combinations thereof.

[0012] The present subject matter may include the use of coated metal foils and metal foils comprising one or more metals in combination with one or more agents. It is also contemplated that instead of, or in addition to, one or more metal foils for a substrate of the viscoelastic damping material laminate, one or more polymeric films or coatings could be utilized. In one embodiment, the metal foil may comprise metalized film.

[0013] The present subject matter also may comprise other materials for the substrate(s) such as heterogeneous layers or regions. In some embodiments, the substrate(s) may comprise one or more adjuvants dispersed in a matrix material. The adjuvants may, for example, be in the form of particles, platelets, fibers, geometrically shaped materials, and/or sheet-like regions of a first material different in chemical composition from the matrix material. A particular example of a heterogeneous layer is a carbon fiber film. In another embodiment, a heterogeneous layer may comprise a polymer composite with at least one layer of fiberglass or carbon fiber. In one example, the fiberglass may be impregnated with epoxy. In another example, the fiberglass may be FR-4 (also known as FR4). In some embodiments, the selection of the adjuvant(s) and of the matrix material and extent of dispersal of the adjuvant(s) within the matrix material enables specific tailoring of the physical properties and characteristics of the heterogeneous layer(s) which may be used as substrate(s). In still other embodiments, the substrate(s) can utilize foils that exhibit compositional gradients or regions such as along the foil thickness. In some embodiments, compositional gradients or regions may provide a gradual change in material properties from one surface to another surface. The metal foil may be a differential foil having a first ferrous region of ferrous foil and a second region of a non-ferrous based foil. In some embodiments, a differential foil could be used having two or more regions of a ferrous composition or ferrous-based composition, in combination with two or more regions of a nonferrous composition or nonferrous-based composition.

Viscoelastic Damping Materials

[0014] Each of the viscoelastic damping material layer(s) used in the viscoelastic damping material laminate of the present subject matter are relatively thin. In many embodiments, the relatively thin viscoelastic damping material laminate may have a thickness within a range of from about 2 μm to about 5,000 μm, in many embodiments from about 10 μm to about 1,000 μm, and in certain embodiments have a thickness of about 125 μm. In some embodiments, at least one of the first layer of viscoelastic damping material and the second layer of viscoelastic damping material may comprise a viscoelastic damping material selected from the group comprising, but are not limited to, elastomers, butyl rubber, styrenic block copolymer (known as SBCs, for example, Kraton), polyurethanes, silicone rubbers, nitrile rubber, isoprene, butadiene, viscoelastic polymer gels, pressure sensitive adhesives (for example, silicone,

rubber, acrylic), non-pressure sensitive adhesives, asphaltic materials (for example, roofing adhesives and mastics), and combinations of these. In many embodiments, these viscoelastic damping materials may have a modulus dependent on both temperature and frequency that may provide efficient damping at about their glass transition. In other embodiments, both the first layer of viscoelastic damping material and the second layer of viscoelastic damping material may comprise a viscoelastic damping material selected from the group comprising, but are not limited to, elastomers, butyl rubber, styrenic block copolymer (known as SBCs, for example, Kraton), polyurethanes, silicone rubbers, nitrile rubber, isoprene, butadiene, viscoelastic polymer gels, pressure sensitive adhesives (for example, silicone, rubber, acrylic), non-pressure sensitive adhesives, asphaltic materials (for example, roofing adhesives and mastics), and combinations of these. In many embodiments, these viscoelastic damping materials may have a modulus dependent on both temperature and frequency that may provide efficient damping about their glass transition. In many embodiments, the viscoelastic damping materials may have a tan delta maximum greater than about 0.5 at the temperature and frequency of the damping application. In some embodiments, the temperature range measured by dynamic mechanical analyzer (DMA) at 10 rad/s may be about -120 °C to about 200 °C, in many embodiments -80 °C to about 100 °C, and in some embodiments about - 60 °C to about 75 °C.

[0015] The viscoelastic damping materials used in the tapes of the present subject matter may exhibit viscoelastic properties at temperatures corresponding to the tape applications. Generally, the tapes are used, and/or designed for applications within a temperature range of from -30° C to 150° C. In some embodiments, the present subject matter also includes tapes for use at temperatures which may be less than -30° C and/or greater than 150° C.

[0016] In many embodiments, the adhesives comprise pressure sensitive adhesives (PSAs). However, the present subject matter may also include the use of adhesives which are not pressure sensitive adhesives or "non-PSA's." For example, non-pressure sensitive adhesives may include, but are not limited to, heat seal adhesives, thermal bond films, B-stage adhesives, two-stage adhesives, dry adhesives, and combinations of these.

[0017] The pressure sensitive adhesive materials that can be used in the vibration damping adhesive tapes include rubber based adhesives, acrylic adhesives, vinyl ether adhesives, silicone adhesives, and/or mixtures of two or more thereof. Included are the pressure sensitive adhesive materials described in "Adhesion and Bonding", Encyclopedia of Polymer Science and Engineering, Vol. 1, pages 476-546, Interscience Publishers, 2nd Ed. 1985, the disclosure of which is hereby incorporated by reference. The pressure sensitive adhesive materials may comprise as a major constituent an adhesive polymer such as natural, reclaimed or styrene butadiene rubber, tackified natural or synthetic rubbers, styrene butadiene or styrene isoprene block copolymers, random copolymers of ethylene and vinyl acetate, ethylene-vinyl-acrylic terpolymers, polyisobutylene, poly(vinyl ether), poly(acrylic) ester, etc. The pressure sensitive rubber and acrylic adhesive materials are typically characterized by glass transition temperatures in the range of about -70° C. to about 20° C. The pressure sensitive silicone adhesive materials are typically characterized by glass transition temperatures in the range of

about -20° C to about 100° C.

[0018] The acrylic adhesives may comprise as a major constituent acrylic type polymers containing carboxylic acids which are obtained from vinyl type monomers containing carboxyl groups such as acrylic acid, methacrylic acid, etc., and acrylic type polymers containing hydroxyl groups which are obtained from vinyl type monomers containing hydroxyl groups such as 2-hydroxyethyl methacrylate, etc. In one embodiment, the acrylic adhesive material is obtained from the copolymerization of an alkyl acrylate such as butyl acrylate, 2-ethylhexyl acrylate, or isononyl acrylate; a polar monomer such as acrylic acid, acrylamide, or N-vinyl-2-pyrrolidone, and another monomer such as an acrylate other than the acrylate mentioned above, methacrylate, styrene, vinyl acetate, etc.

[0019] Other materials in addition to the foregoing resins may be included in the pressure sensitive adhesive materials. These may include, but are not limited to, solid tackifying resins, liquid tackifiers (often referred to as plasticizers), antioxidants, fillers, pigments, waxes, etc. The adhesive materials may contain a blend of solid tackifying resins and liquid tackifying resins (or liquid plasticizers).

[0020] In many embodiments, the viscoelastic damping materials exhibit, in addition to improved vibration damping characteristics, beneficial adhesion characteristics such as relatively high adhesion, good shear resistance, good temperature resistance, good chemical resistance, weatherability and resistance to environmental agents including UV radiation, good holding power, adhesion to low surface energy substrates, and adhesion to non-pristine surfaces such as dirty or oily surfaces, as may be found in certain automotive applications.

[0021] The first layer of viscoelastic damping material and the second layer of viscoelastic damping material in the present subject matter utilize different chemical compositions. In another embodiment, all layers of viscoelastic damping material (where there are at least three layers of viscoelastic damping materials) may have different chemical compositions.

[0022] The viscoelastic damping material layers (referring to both the first layer of viscoelastic damping material and the second layer of viscoelastic damping material) in the present subject matter tapes can be continuous or substantially continuous. In many embodiments, the viscoelastic damping material layers are continuous and exhibit a uniform thickness. In some embodiments, the viscoelastic damping material layers may be substantially continuous where the layer(s) may be not uniform, such as unintentional defects or voids.

Release Liner(s)

[0023] The viscoelastic damping material laminates of the present subject matter optionally comprise one or more release liner(s) at least partially covering or disposed on the viscoelastic damping material layer(s). Generally, in many embodiments, a first release liner is at least partially disposed on and covering a face of a first viscoelastic damping material layer of

viscoelastic damping material. Optionally, a second release liner may be at least partially disposed on and covering a face of a second layer of viscoelastic damping material. The present subject matter includes the use of a multi-component release liner assembly such as a plurality of release liners at least partially covering a region of an otherwise exposed viscoelastic damping material layer. In certain embodiments, the tapes may comprise a plurality of release liners, a single release liner, or be free of release liner(s).

[0024] Release liners for use in the present subject matter may be those known in the art. Various release liners are available that may be applied to the viscoelastic damping material and are useful in protecting the viscoelastic damping material from inadvertently bonding prior to use. Suitable release liners are described in some detail in Chapter 23 of the Handbook of Pressure Sensitive Adhesive Technology, 2nd Ed., edited by Donatas Satas. Various release liners known in the art are suitable as long as they are selected for their release characteristics relative to the viscoelastic damping material chosen for use in the present subject matter.

Composite Loss Factor and Damping Efficiency

[0025] As provided herein, damping performance may be measured using CLF (composite loss factor) over a certain temperature range at a reference frequency of at least 50 Hz. In some embodiments, 200 Hz may be used as the reference frequency. In some embodiments, a laminate construction may be considered to be damping when the CLF is at least 0.10 at a frequency of 200Hz at the temperature range of the application. The temperature range of the application may be about -50 °C to about 200 °C. In some embodiments, a laminate construction may be considered to be damping when the CLF is at least 0.05 when measured over a temperature range of 15 °C at a frequency of 200 Hz. As described herein, the span for the temperature range of 15 °C may occur from about -50 °C to about 200 °C. In other embodiments, a laminate construction may be considered to be damping when the CLF is at least 0.10 when measured over a temperature range of 15 °C at a frequency of 200 Hz where the span for the temperature range of 15 °C may occur from about -50 °C to about 200 °C.

[0026] In other embodiments, the damping properties of laminate constructions may be based on the damping efficiency index (described below). In one embodiment, a laminate construction may have a damping efficiency index of at least greater than 2000 at frequencies of at least about 50 Hz. In another embodiment, a laminate construction may have a damping efficiency index of at least greater than 2000 at frequencies of about 50 Hz to about 5000 Hz.

[0027] As used herein, damping efficiency is a measure of the composite loss factor (CLF) height and width normalized by its thickness and mass. For damping efficiency, the performance of different tapes may be evaluated using the linear-density normalized damping efficiency index, $\zeta = (W \times M)/(\rho_A \times t)$ (with units of °C /(kg/m)), where, W is the width of the CLF curve for CLF ≥ 0.10 (in °C), M is the maximum value of measured CLF, ρ_A is mass per unit area (kg/m^2) and t is the thickness of the total construction (m). In some embodiments of

what is disclosed herein, samples with improved damping may have a linear-density normalized damping efficiency index (ζ) that is greater than at least 2.0×10^3.

Figures

[0028] Figure 1 is a schematic cross sectional view of an embodiment of a tape 10 in accordance with the present subject matter. The tape 10 comprises a substrate 40 defining a first face 42 and an oppositely directed second face 44. The tape 10 also comprises a first layer of viscoelastic damping material 30 at least partially disposed on or along the first face 42 of the substrate 40. The tape 10 additionally comprises a second layer of viscoelastic damping material 50 at least partially disposed on or along the second face 44 of the substrate 40. The tape 10 may also comprise one or more optional release liner(s) such as a release liner 20 at least partially disposed on and covering the first layer of viscoelastic damping material 30 and/or a release liner 60 at least partially disposed on and covering the second layer of viscoelastic damping material 50.

[0029] Figure 2 is a schematic cross sectional illustration of another embodiment of a tape 100 in accordance with the present subject matter. The tape 100 comprises a first substrate 110, a second substrate 130, a first layer of viscoelastic damping material 120 at least partially disposed between the first and second substrates 110 and 130, and a second layer of viscoelastic damping material 140. The second substrate 130 is at least partially disposed between the first layer of viscoelastic damping material 120 and the second layer of viscoelastic damping material 140. The tape 100 also comprises an optional release liner 150 at least partially disposed on or along the second viscoelastic damping material layer of viscoelastic damping material 140.

Tape Forms

[0030] The tapes of the present subject matter can be provided in a variety of different forms. In many embodiments, the tapes are provided in a roll form, however other forms are included such as sheet forms and Z-fold forms.

Applications and Constrained layer systems

[0031] As noted, the tapes of the present subject matter will find wide application for damping vibration. When applied, i.e., adhered to the first component, a constrained layer system is formed. The tapes of the present subject matter may also be applied (i.e. adhered) to an optional second component. Upon the first component and optional second component undergoing vibration, the tape and particularly the viscoelastic damping material layer(s) of the tape dampen or reduce the vibration. Although not wishing to be limited to any particular

frequency or range of frequencies, the tapes of the present subject matter will find use in damping vibrations of at least 50 Hz. In other embodiments, the tapes of the present subject matter may dampen vibrations within a frequency range of from about 50 Hz to about 15,000 Hz, more typically from about 100 Hz to about 5,000 Hz, and in particular applications from about 200 Hz to about 3,000 Hz.

[0032] The tapes of the present subject matter can potentially be used in any application in which it is desired to dampen vibration by forming a constrained layer system by adhering the tape to a first component exhibiting or undergoing vibration and optionally, a second component of the system. The tapes of the present subject matter can also potentially be used in any application in which it is desired to dampen vibration by forming a constrained layer system by adhering (i.e. applying) the tape to at least one of the first component and the second component of the system exhibiting or undergoing vibration. Non-limiting examples include automotive applications, electronic applications, incorporation in power tools, aerospace applications, incorporation in domestic appliances such as in washers, dryers, dishwashers, and in industrial equipment such as motor housings and pump housings. Specific non-limiting examples of automotive applications include automotive door panels, brake components including brake pads and brake shims, roofs, floors, heat shields, frames and frame components, firewalls, and suspension components. A non-limiting example of an electronic application is damping vibration associated with a hard disk drive (HDD).

[0033] Figures 3 and 4 are schematic cross sectional views of constrained layer systems using the tape 10 previously described in association with Figure 1. The constrained layer system 210 depicted in Figure 3 comprises the tape 10 (comprised of a substrate 40, a first layer of adhesive 30, and a second layer of adhesive 50) having one of its release liners removed (e.g., release liner 60 shown in Figure 1), and the tape 10 being at least partially adhered via viscoelastic damping material layer 50 to a second component 70 undergoing vibration or potential vibration to be damped. The constrained layer system 212 shown in Figure 4 comprises the tape 10 having both of its release liners removed (e.g., release liners 20 and 60 shown in Figure 1), and the tape 10 being adhered via a second layer of viscoelastic damping material layer 50 to a second component 70 undergoing vibration or potential vibration to be damped, and adhered via the first layer of viscoelastic damping material 30 to a first component 80 undergoing vibration or potential vibration to be damped. Referring further to Figure 4, it will be understood that the first component 80 and/or the second component 70 could in many applications be in the form of an acoustic absorbing material such as a foam. The resulting assembly would provide both vibration damping and acoustic absorption. It is also understood that additional layers of substrates and/or layers of adhesive may be added in Figures 3 and 4.

[0034] Figure 5 is a schematic cross sectional view of a constrained layer system using the tape 100 previously described in association with Figure 2. The constrained layer system 300 comprises the tape 100 having its release liner removed (e.g., release liner 150 shown in Figure 2), and the tape 100 being adhered via a second layer of adhesive 140 (also referred to as a second layer of viscoelastic damping material herein) to a second component 170

undergoing vibration or potential vibration to be damped. In Figure 5, the first substrate is exposed and not adhered or bonded to another substrate, viscoelastic damping material, or component. Conversely (but not shown in Figure 5), the tape may be adhered vis a first layer of adhesive (also referred to as a first layer of viscoelastic damping material herein) to a first component undergoing vibration or potential vibration to be damped where the second substrate is exposed and not adhered or bonded to another substrate, viscoelastic damping material, or component. It is also understood that additional layers of substrates and/or layers of adhesive may be added in Figure 5, where a substrate is still exposed and not adhered or bonded to another substrate, viscoelastic damping material, or component.

[0035] The embodiments described in Figures 1-5 provide examples of a configuration described herein. It is understood that the present subject matter may include tapes having additional substrates, including three substrates, four substrates, five substrates, and six or more substrates. The additional substrates may be disposed upon each other or disposed on at least one viscoelastic damping layer. It is also understood that the present subject matter may include tapes having additional viscoelastic damping layers, including three viscoelastic damping material layers, four viscoelastic damping material layers, five viscoelastic damping material layers, or six or more viscoelastic damping material layers. The additional viscoelastic damping layers may be disposed upon each other or disposed on at least one substrate.

[0036] Figures 6, 7, and 8 are described below in the Examples.

Examples

[0037] Vibration damping characteristics of several adhesive tapes in accordance with the present subject matter were compared to the vibration damping characteristics of commercially available vibration damping adhesives tapes. For the commercially available vibration damping adhesive tapes, the laminates described herein were evaluated at similar thicknesses in some embodiments. In some instances, varying thicknesses were evaluated to demonstrate both the increased vibration damping efficiency index and CLF. Specifically, a tape available from Avery Dennison under the designation UHA 0806 was obtained and designated as Sample A. The UHA 0806 tape includes an aluminum foil with a single layer of acrylic adhesive (as the viscoelastic damping material) at least partially disposed on one face of the aluminum foil. The UHA 0806 tape utilizes an adhesive layer coat weight of 125 g/m^2 and has total thickness of 0.25 mm. The total product mass per unit area for the UHA 0806 tape is 0.45 kg/m^2. This is the mass per unit area for the full tape, i.e., adhesive plus foil.

[0038] Another tape similar to the construction of Sample A, from Dynamic Control of North America, Inc. under the designation DYNAMAT SUPERLITE was obtained and designated as Sample B. The DYNAMAT SUPERLITE tape includes a 0.06 mm aluminum foil and a single layer of adhesive (as he viscoelastic damping material) on one face of the foil. The DYNATMAT SUPERLITE tape utilizes a relatively high coat weight black butyl adhesive with a total product

mass per unit area of 1.50 kg/m^2 and total thickness of 1.10 mm.

[0039] A tape not in accordance with the present subject matter and having a configuration corresponding to that shown in Figure 2 was prepared and designated as Sample C, which has a total mass of 1.50 kg/m^2. That tape utilized an acrylic adhesive for each of the two adhesive layers (as the viscoelastic damping material), each adhesive layer having a coat weight of 125 g/m^2 and a thickness of 0.125 mm and each adhesive layer having the same chemical composition. That tape also utilized an aluminum foil for each of the substrates, each foil layer having a thickness of 0.250 mm.

[0040] A tape in accordance with the present subject matter and having a configuration corresponding to that shown in Figure 2 was prepared and designated as Sample D, which has a total mass of 1.50 kg/m^2. That tape utilized an acrylic adhesive for each of the two adhesive layers (as the viscoelastic damping material), each adhesive layer having a coat weight of 125 g/m^2 and a thickness of 0.125 mm and each adhesive layer having different chemical composition. That tape also utilized an aluminum foil for each of the substrates, each foil layer having a thickness of 0.250 mm.

[0041] A tape in accordance with the present subject matter and having a configuration corresponding to that shown in Figure 2 was prepared and designated as Sample E, which has a total mass of 0.90 kg/m^2. That tape utilized an acrylic adhesive for each of the two adhesive layers (as the viscoelastic damping material), each adhesive layer having a coat weight of 125 g/m^2 and a thickness of 0.125 mm. That tape also utilized an aluminum foil for each of the substrates, each foil layer having a thickness of 0.125 mm.

[0042] Each of the tape samples A, B, C, D and E was adhered to a component which was then subjected to vibration over a range of temperatures. The Composite Loss Factor (CLF) was then determined for each system. As is known in the art, a CLF value is an indication of a tape's (or other construction) damping ability. In general, the greater the value of the CLF at a given temperature, the greater the ability of the tape to dampen or reduce vibration at that temperature. The CLF measurements for each sample were obtained from a vibrating beam test (VBT) using specification SAE J1637 with 0.75 mm thick Sendimizer steel as the base layer (component) and the results are reported at a reference frequency of 200 Hz.

[0043] As evident in the graph of Figure 6, the tape Sample D exhibited higher CLF values over a relatively wide range of temperatures as compared to currently available tapes, i.e., Sample A and Sample B. Sample C exhibited a slightly higher peak CLF than Sample D and has a higher peak CLF than Sample B, and an overall higher CLF over the temperature range evaluated than Sample A. Sample E exhibited comparable CLF values to that of Sample B. Samples C, D, and E are all thinner and lighter than or equivalent in weight to Sample B. The present subject matter allows for construction of tapes having equivalent thickness and weight profiles, if not, thinner and lighter profiles, than currently available tapes, with broader and/or

higher CLF values as a function of temperature (as seen in Figure 6).

[0044] Another tape, of thickness and weight higher than Samples A - E, from Dynamic Control of North America, Inc. under the designation DYNAMAT XTREME was obtained and designated as Sample F. The DYNAMAT XTREME tape includes a 0.10 mm aluminum foil and a single layer of adhesive on one face of the foil. The DYNAMAT XTREME tape utilizes a relatively high coat weight black butyl adhesive with total product mass per unit area of 2.50 kg/m^2 and total thickness of 1.7 mm.

[0045] Another tape, of thickness and weight equivalent to Sample F, from Sika Corporation, under the designation SikaDamp 630 was obtained and designated as Sample G. The SikaDamp 630 tape includes a 0.08 mm aluminum foil and a single layer of adhesive on one face of the foil. The SikaDamp 630 tape utilizes a relatively high coat weight black butyl adhesive with a total product mass per unit area of 2.00 kg/m^2 and total thickness of 1.5 mm.

[0046] A tape in accordance with the present subject matter and having a configuration corresponding to that shown in Figure 2 was prepared and designated as Sample H. That tape utilized an acrylic adhesive for each of the two adhesive layers, each adhesive layer having a thickness of 1.0 mm. That tape also utilized an aluminum foil for each of the substrates, each foil layer having a thickness of 0.125 mm.

[0047] A tape not in accordance with the present subject matter and having a configuration comprising of two layers of Sample C was prepared and designated as Sample I. That tape utilized an acrylic adhesive for each of the four adhesive layers (as the viscoelastic damping material), each adhesive layer having a coat weight of 125 g/m^2 and a thickness of 0.125 mm. That tape also utilized an aluminum foil for each of the four substrates, each foil layer having a thickness of 0.25 mm.

[0048] As evident in the graph of Figure 7, the tape Sample D exhibited comparable CLF values over a relatively wide range of temperatures as compared to currently available tapes, i.e., Sample F and Sample G. However, Sample D is both thinner and lighter than Sample F and G. Sample H has higher CLF values over the entire temperature range studied than the CLF values of currently available tapes, i.e., Sample F and Sample G. However, Sample H has mass per unit area comparable to that of Sample F and Sample G. Sample I exhibits the highest maximum in CLF amongst all the samples studied. Therefore, this present subject matter provides damping constructions that allows for both higher CLF values as well as broader (or comparable in breadth) CLF value as a function of temperature with reduced tape thickness and reduced tape mass per unit area.

[0049] Figure 8 provides a measure of damping efficiency, calculated at 200 Hz, as described herein. Figure 8 provides plots of the linear-density normalized damping efficiency index (ζ) for Samples A through I. With currently available samples (Sample A, B, F and G), the linear-density normalized damping efficiency index (ζ) is less than about 4.5×10^3. For the products

disclosed (Samples C, D, E, H, and I), the linear-density normalized damping efficiency index (ζ) is greater than at least about 4.5×10^3. For products with a more optimized surface density for maximal temperature-dependent damping (those with ζ is greater than at least about 4.5×10^3), the linear-density normalized damping efficiency index is increased. For instance, Sample A has the linear-density normalized damping efficiency index (ζ) at about 0 because its peak CLF is less than 0.10 (Fig. 6) despite being light. Sample F and Sample G, despite having significant portion of the CLF value greater than 0.10 (see Fig. 7), have ζ at about 4.4×10^3 due to their relatively high surface density. In comparison, Samples C, D and E have $\zeta > 1.12 \times 10^4$ by virtue of having comparable or better damping (see Fig. 6) where the samples have about a 50% reduction in surface density. Similarly, comparing Samples H and Sample I to equivalent heavy products like Sample F and Sample G, Sample H and Sample I have at least comparable if not improved damping, as measured by the linear-density normalized damping efficiency index (see Fig. 7 and Fig. 8). In some embodiments (not shown) of what is disclosed herein, samples with improved damping may have a linear-density normalized damping efficiency index (ζ) that is greater than at least 2.0×10^3.

[0050] Many other benefits will no doubt become apparent from future application and development of this technology.

[0051] The present subject matter includes all operable combinations of features and aspects described herein. Thus, for example if one feature is described in association with an embodiment and another feature is described in association with another embodiment, it will be understood that the present subject matter includes embodiments having a combination of these features.

[0052] As described hereinabove, the present subject matter solves many problems associated with previous strategies, systems and/or devices. However, it will be appreciated that various changes in the details, materials and arrangements of components, which have been herein described and illustrated in order to explain the nature of the present subject matter, may be made by those skilled in the art without departing from the principle and scope of the claimed subject matter, as expressed in the appended claims.

REFERENCES CITED IN THE DESCRIPTION

Cited references

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all

liability in this regard.

Patent documents cited in the description

- US3160549A [0002]
- US2819032A [0002]

Non-patent literature cited in the description

- Adhesion and BondingEncyclopedia of Polymer Science and EngineeringInterscience Publishers19850000vol. 1, 476-546 [0017]
- Handbook of Pressure Sensitive Adhesive Technology [0024]

PATENTKRAV

1. Bånd (10) til dæmpning, hvor båndet omfatter:

et substrat (40), som har en første flade og en modsat rettet anden flade;
et første lag af viskoelastisk dæmpningsmateriale (30) i det mindste delvis anbragt på den første flade af substratet (40); og
et andet lag af viskoelastisk dæmpningsmateriale (50) i det mindste delvis anbragt på den anden flade af substratet (40);
hvor substratet (40) har en tykkelse i et område fra ca. 5 µm til ca. 3000 µm, og hvert af de viskoelastiske dæmpningsmaterialelag (30, 50) har en tykkelse i et område fra ca. 2 µm til ca. 5000 µm,
kendetegnet ved, at
det første lag af viskoelastisk dæmpningsmateriale (30) og det andet lag af viskoelastisk dæmpningsmateriale (50) har forskellige kemiske sammensætninger.

2. Bånd ifølge krav 1, hvor substratet har et område for Young's modul ved rumtemperatur på ca. 1 GPa til ca. 1000 GPa, såsom ca. 20 GPa til ca. 500 GPa.

3. Bånd ifølge krav 1, hvor substratet omfatter en metalfolie, såsom en jernfolie eller en ikke-jernbaseret folie.

4. Bånd ifølge krav 3, hvor metalfolien er en differensfolie med et første område af en jernbaseret folie og et andet område af en ikke-jernbaseret folie.

5. Bånd ifølge krav 3, hvor metalfolien omfatter aluminium.

6. Bånd ifølge krav 1, hvor i det mindste ét af det første lag af viskoelastisk dæmpningsmateriale og det andet lag af viskoelastisk dæmpningsmateriale omfatter viskoelastiske dæmpningsmaterialer valgt fra gruppen omfattende elastomerer, butylgummi, styrenblok-copolymer, polyurethaner, silikonegummier, nitrilgummi, isopren, butadien, viskoelastiske polymergeler, trykfølsomme klæbere, ikke-trykfølsomme klæbere og kombinationer deraf, eller
hvor såvel det første lag af viskoelastisk dæmpningsmateriale som det andet lag af viskoelastisk dæmpningsmateriale er valgt gruppen omfattende elastomerer, butylgummi, styrenblok-copolymer, polyurethaner, silikonegummier, nitrilgummi, isopren,

butadien, viskoelastiske polymergeler, trykfølsomme klæbere, ikke-trykfølsomme klæbere og kombinationer deraf.

7. Bånd ifølge krav 6, hvor de trykfølsomme klæbere omfatter en acrylklæber, en silikoneklæber, en gummiklæber, en vinyletherklæber og kombinationer deraf.

8. Bånd ifølge krav 1, hvor i det mindste ét af det første lag af viskoelastisk dæmpningsmateriale og det andet lag af viskoelastisk dæmpningsmateriale er i det væsentlige kontinuert.

9. Bånd ifølge krav 1, som yderligere omfatter:
i det mindste ét skillelag i det mindste delvis anbragt på i det mindste et af det første lag af viskoelastisk dæmpningsmateriale og det andet lag af viskoelastisk dæmpningsmateriale.

10. Bånd ifølge krav 1, som yderligere omfatter:
et første skillelag i det mindste delvis anbragt på det første lag af viskoelastisk dæmpningsmateriale og
et andet skillelag i det mindste delvis anbragt på det andet lag af viskoelastisk dæmpningsmateriale.

11. Tvunget lagsystem omfattende:

i det mindste en af en første komponent og en anden komponent, som udsættes for vibration; og
dæmpningsbåndet ifølge ethvert af kravene 1 til 10, hvor det første lag af viskoelastisk dæmpningsmateriale er klæbet til den første komponent.

12. Tvunget lagsystem ifølge krav 11, hvor det første lag af viskoelastisk dæmpningsmateriale er klæbet til den første komponent, idet systemet yderligere omfatter:
det andet lag af viskoelastisk dæmpningsmateriale er klæbet til den anden komponent.

13. Bånd ifølge krav 1 eller det tvungne lagsystem ifølge krav 11, som yderligere omfatter yderligere substrater, eller yderligere omfattende yderligere viskoelastiske dæmpningslag.

14. Bånd ifølge krav 1 eller det tvungne lagsystem ifølge krav 11, hvor CLF er i det mindste omkring 0,05 over et område på omkring 15°C ved omkring 200 Hz, såsom i det mindste omkring 0,10 over et område på omkring 15°C ved omkring 200 Hz.

15. Bånd ifølge krav 1 eller tvunget lagsystem ifølge krav 11, hvor det lineære densitet normaliserede dæmpningseffektivitetsindeks (ζ) er større end i det mindste 2,0 x 10^3 ved 200 Hz, såsom større end i det mindste 4,5 x 10^3 ved 200 Hz.

DRAWINGS

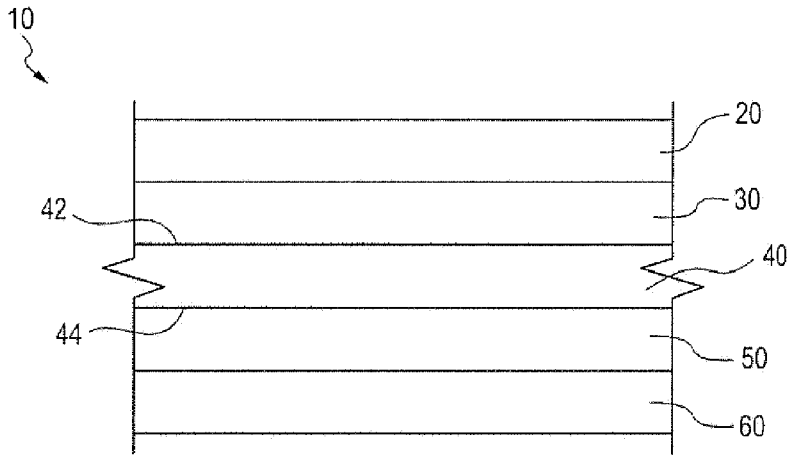


FIG. 1

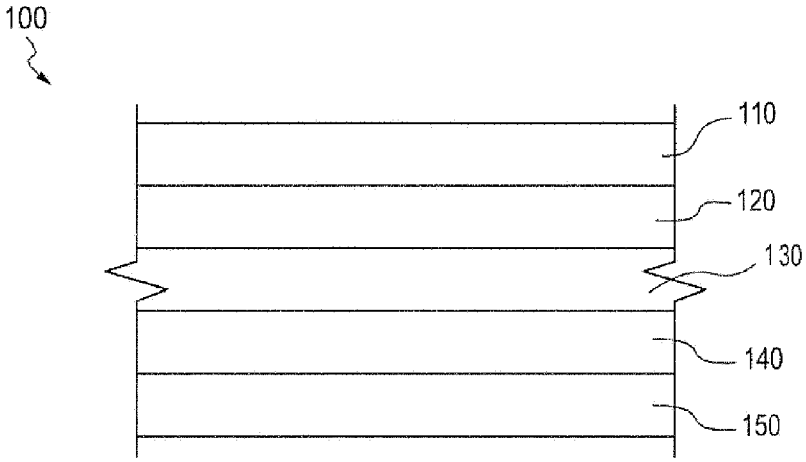


FIG. 2

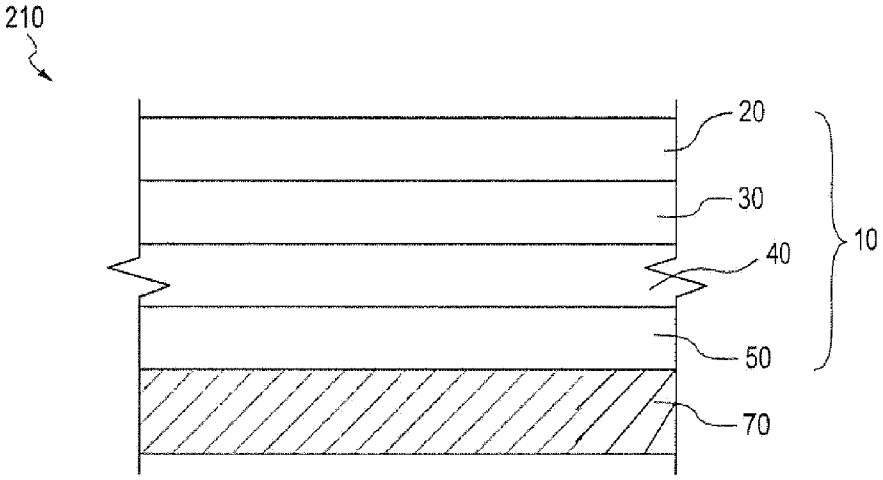


FIG. 3

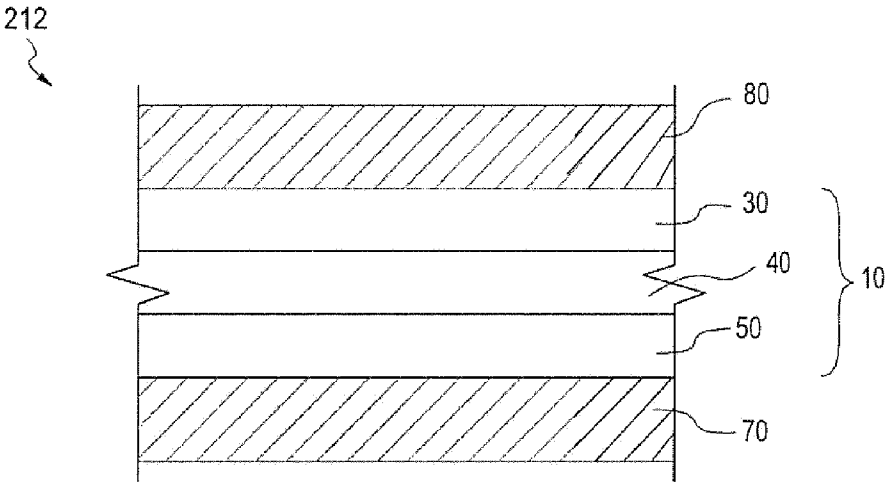


FIG. 4

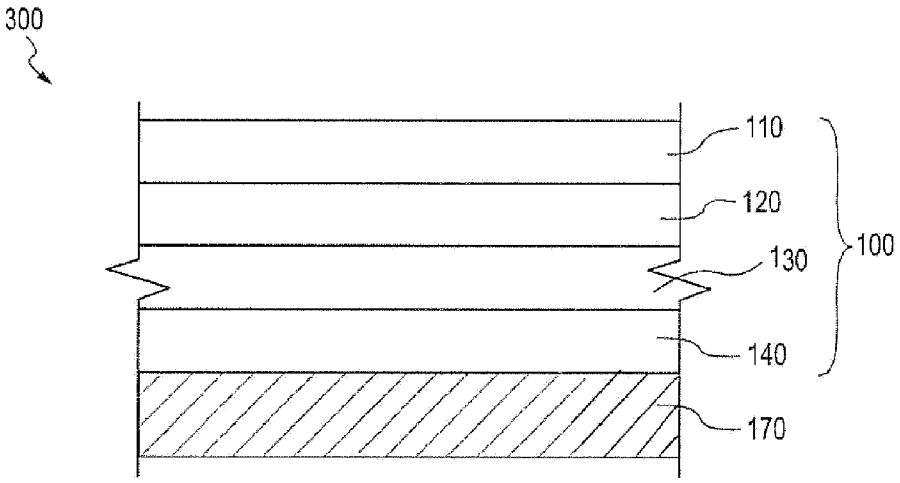


FIG. 5

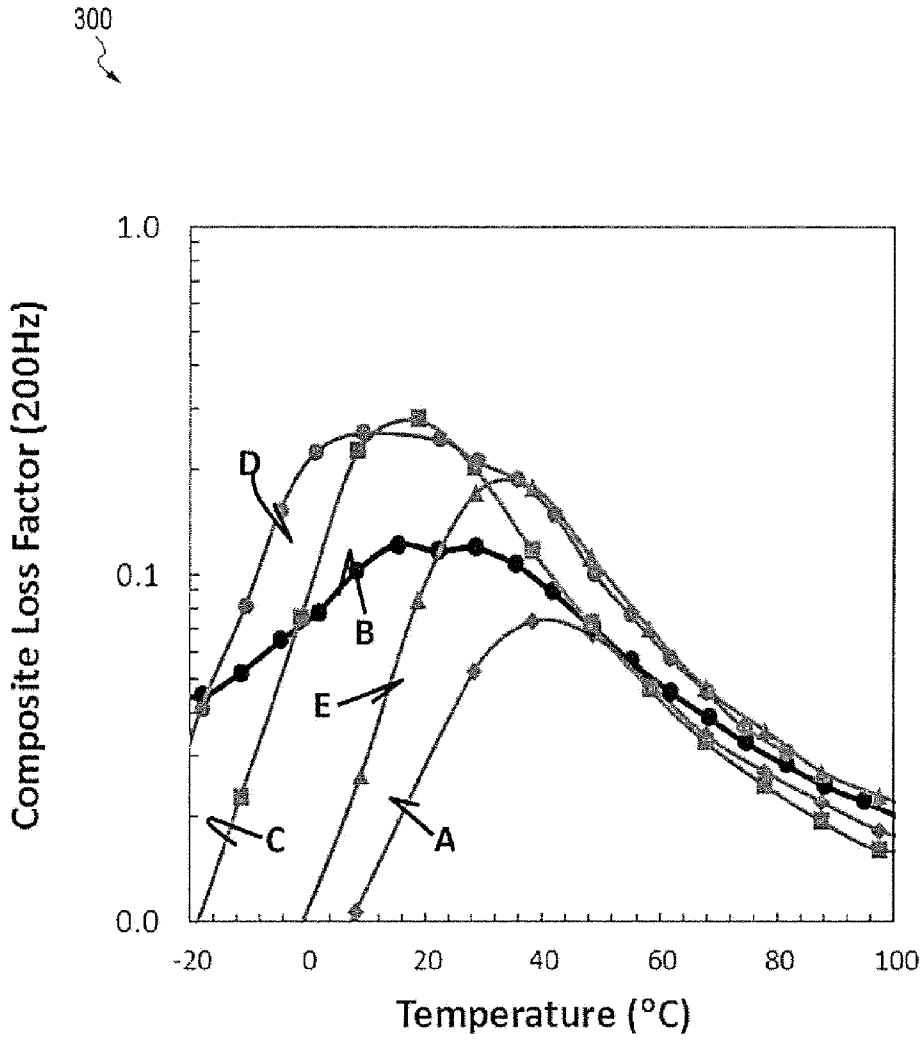

300
1.0
0.1
0.0
Composite Loss Factor (200Hz)
D
B
E
C
A
-20
0
20
40
60
80
100
Temperature (°C)

FIG. 6

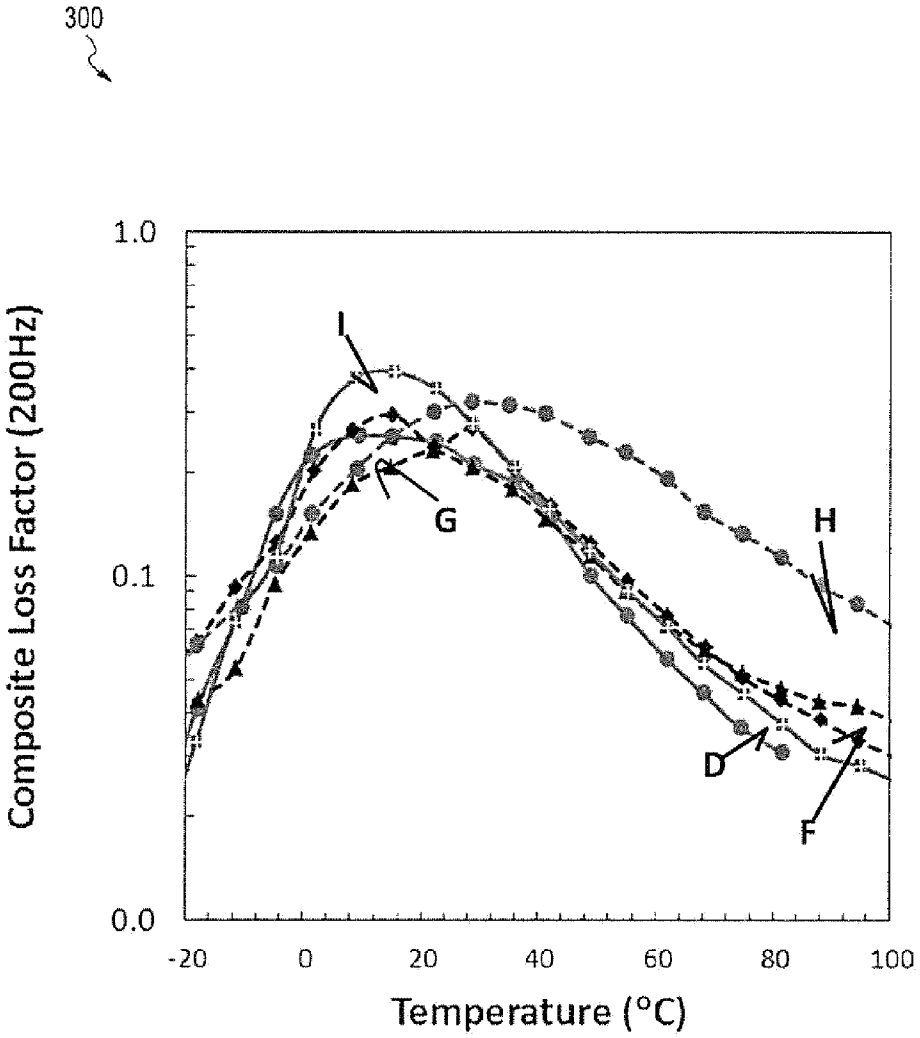

300
1.0
0.1
0.0
Composite Loss Factor (200Hz)
-20
0
20
40
60
80
100
Temperature (°C)
I
G
H
D
F

FIG. 7

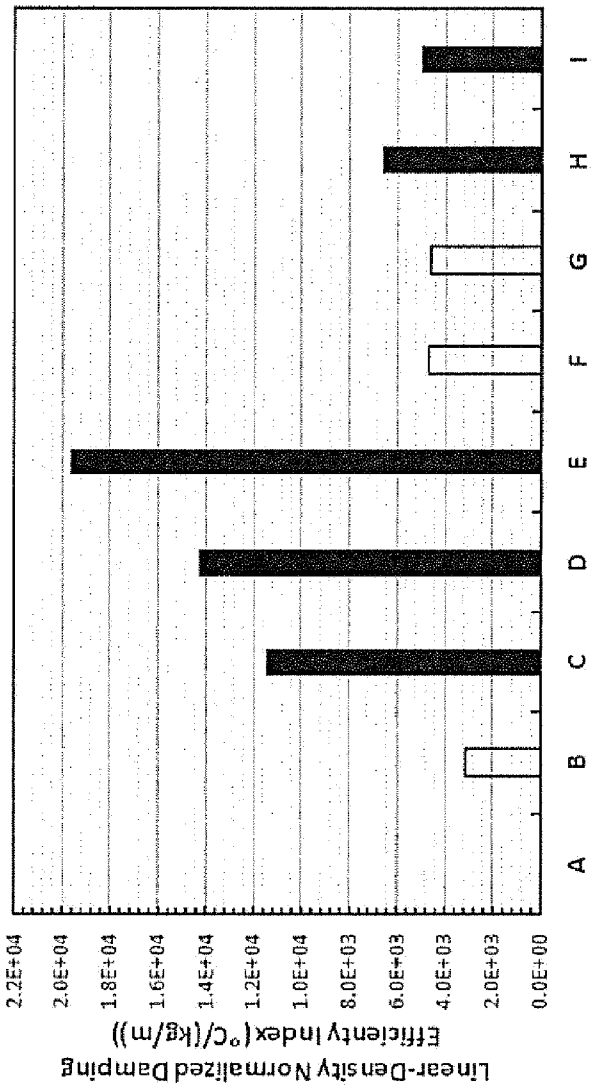

Linear-Density Normalized Damping Efficienty Index(°C/(kg/m))
2.2E+04
2.0E+04
1.8E+04
1.6E+04
1.4E+04
1.2E+04
1.0E+04
8.0E+03
6.0E+03
4.0E+03
2.0E+03
0.0E+00
A
B
C
D
E
F
G
H
I

FIG. 8