CLAIMS

We claim:

1. A vibrating member (500) for a vibrating densitometer (800), comprising:

an inner surface (531) including:

one or more arcuate portions (730); and

two or more raised portions (530), wherein a first of the two or more raised portions (530) comprises a straight portion, and a second of the two or more raised portions (530) comprises a projecting bump, wherein the two or more raised portions (530) are sized and located to increase a frequency separation between a resonant frequency of a desired vibrational drive mode and a resonant frequency of one or more undesired vibrational modes.

2. The vibrating member (500) of claim 1, wherein the desired drive mode comprises a first three-lobed radial vibrational mode and an undesired vibrational mode comprises a second three-lobed radial vibrational mode.

3. The vibrating member (500) of claim 1, wherein the one or more raised portions (530) extend an entire length of the vibrating member (500).

4. The vibrating member (500) of claim 1, wherein the one or more arcuate portions (730) comprise a first thickness, $D_1$, and the one or more raised portions (530) comprise a second thickness, $D_2$, wherein $D_1$ is less than $D_2$.

5. A vibrating densitometer (800), comprising:

a housing (801);

a vibrating member (500) located at least partially within the housing (801) and including:

an inner surface (531) with one or more arcuate portions (730) and two or more raised portions (530) sized and located to increase a frequency separation between a resonant frequency of a desired vibrational drive mode and a resonant frequency of one or more

undesired vibrational modes, wherein a first of the two or more raised portions (530) comprises a straight portion, and a second of the two or more raised portions (530) comprises a projecting bump.

6. The vibrating densitometer (800) of claim 5, wherein the vibrating member (500) comprises a first end (513) cantilever mounted to the housing (801) such that a second end (514) opposite the first end (513) is free to vibrate.

7. The vibrating densitometer (800) of claim 5, further comprising a driver (516) and one or more sensors (517) configured to vibrate the vibrating member (500) with respect to the housing (801).

8. The vibrating densitometer (800) of claim 5, wherein the desired vibrational drive mode comprises a first three-lobed radial vibrational mode and an undesired vibrational mode comprises a second three-lobed radial vibrational mode.

9. The vibrating densitometer (800) of claim 5, wherein the one or more raised portions (530) extend an entire length of the vibrating member (500).

10. The vibrating densitometer (800) of claim 5, wherein the one or more arcuate portions (730) comprise a first thickness, $D_1$, and the one or more raised portions (530) comprise a second thickness, $D_2$, wherein $D_1$ is less than $D_2$.

11. A method for forming a vibrating densitometer including a vibrating member adapted to vibrate at one or more resonant frequencies, comprising a step of:

forming an inner surface of the vibrating member with one or more arcuate portions and two or more raised portions sized and located to increase a frequency separation between a resonant frequency of a desired vibrational drive mode and a resonant frequency of one or more undesired vibrational modes, wherein a first of the two or more raised portions (530)

comprises a straight portion, and a second of the two or more raised portions (530) comprises a projecting bump.

12. The method of claim 11, wherein the desired vibrational drive mode comprises a first three-lobed radial vibrational mode and an undesired vibrational mode comprises a second three-lobed radial vibrational mode.

13. The method of claim 11, wherein the step of forming the inner surface comprises extending the one or more raised portions the entire length of the vibrating member.

14. The method of claim 11, wherein the step of forming the inner surface comprises forming the one or more arcuate portions with a first thickness, $D_1$, and forming the one or more raised portions with a second thickness, $D_2$, wherein $D_1$ is less than $D_2$.

15. The method of claim 11, further comprising a step of coupling a first end of the vibrating member to a housing such that at least a portion of the vibrating member is located within the housing.

16. The method of claim 15, wherein the step of coupling comprises cantilever mounting the first end to the housing such that a second end of the vibrating member opposite the first end is free to vibrate.

17. The method of claim 11, further comprising steps of positioning a driver and one or more vibrating sensors proximate the vibrating member to induce and sense vibrations of the vibrating member.

18. The method of claim 11, wherein the step of forming comprises cutting the one or more arcuate portions and one or more raised portions using wire electrical discharge machining.

CLAIMS

We claim:

1. A vibrating member (500) for a vibrating densitometer (800), comprising:

an inner surface (531) including:

one or more arcuate portions (730); and

two or more raised portions (530), wherein a first of the two or more raised portions (530) comprises a straight portion, and a second of the two or more raised portions (530) comprises a projecting bump, wherein the two or more raised portions (530) are sized and located to increase a frequency separation between a resonant frequency of a desired vibrational drive mode and a resonant frequency of one or more undesired vibrational modes.

2. The vibrating member (500) of claim 1, wherein the desired drive mode comprises a first three-lobed radial vibrational mode and an undesired vibrational mode comprises a second three-lobed radial vibrational mode.

3. The vibrating member (500) of claim 1, wherein the two or more raised portions (530) extend an entire length of the vibrating member (500).

4. The vibrating member (500) of claim 1, wherein the one or more arcuate portions (730) comprise a first thickness, $D_1$, and the two or more raised portions (530) comprise a second thickness, $D_2$, wherein $D_1$ is less than $D_2$.

5. A vibrating densitometer (800), comprising:

a housing (801);

a vibrating member (500) located at least partially within the housing (801) and including:

an inner surface (531) with one or more arcuate portions (730) and two or more raised portions (530) sized and located to increase a frequency separation between a resonant frequency of a desired vibrational drive mode and a resonant frequency of one or more

undesired vibrational modes, wherein a first of the two or more raised portions (530) comprises a straight portion, and a second of the two or more raised portions (530) comprises a projecting bump.

6. The vibrating densitometer (800) of claim 5, wherein the vibrating member (500) comprises a first end (513) cantilever mounted to the housing (801) such that a second end (514) opposite the first end (513) is free to vibrate.

7. The vibrating densitometer (800) of claim 5, further comprising a driver (516) and one or more sensors (517) configured to vibrate the vibrating member (500) with respect to the housing (801).

8. The vibrating densitometer (800) of claim 5, wherein the desired vibrational drive mode comprises a first three-lobed radial vibrational mode and an undesired vibrational mode comprises a second three-lobed radial vibrational mode.

9. The vibrating densitometer (800) of claim 5, wherein the two or more raised portions (530) extend an entire length of the vibrating member (500).

10. The vibrating densitometer (800) of claim 5, wherein the one or more arcuate portions (730) comprise a first thickness, $D_1$, and the two or more raised portions (530) comprise a second thickness, $D_2$, wherein $D_1$ is less than $D_2$.

11. A method for forming a vibrating densitometer including a vibrating member adapted to vibrate at one or more resonant frequencies, comprising a step of:

forming an inner surface of the vibrating member with one or more arcuate portions and two or more raised portions sized and located to increase a frequency separation between a resonant frequency of a desired vibrational drive mode and a resonant frequency of one or more undesired vibrational modes, wherein a first of the two or more raised portions (530)

comprises a straight portion, and a second of the two or more raised portions (530) comprises a projecting bump.

12. The method of claim 11, wherein the desired vibrational drive mode comprises a first three-lobed radial vibrational mode and an undesired vibrational mode comprises a second three-lobed radial vibrational mode.

13. The method of claim 11, wherein the step of forming the inner surface comprises extending the two or more raised portions the entire length of the vibrating member.

14. The method of claim 11, wherein the step of forming the inner surface comprises forming the one or more arcuate portions with a first thickness, $D_1$, and forming the two or more raised portions with a second thickness, $D_2$, wherein $D_1$ is less than $D_2$.

15. The method of claim 11, further comprising a step of coupling a first end of the vibrating member to a housing such that at least a portion of the vibrating member is located within the housing.

16. The method of claim 15, wherein the step of coupling comprises cantilever mounting the first end to the housing such that a second end of the vibrating member opposite the first end is free to vibrate.

17. The method of claim 11, further comprising steps of positioning a driver and one or more vibrating sensors proximate the vibrating member to induce and sense vibrations of the vibrating member.

18. The method of claim 11, wherein the step of forming comprises cutting the one or more arcuate portions and two or more raised portions using wire electrical discharge machining.