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(54) **GOLF CLUB HEAD WITH SOUND TUNING**

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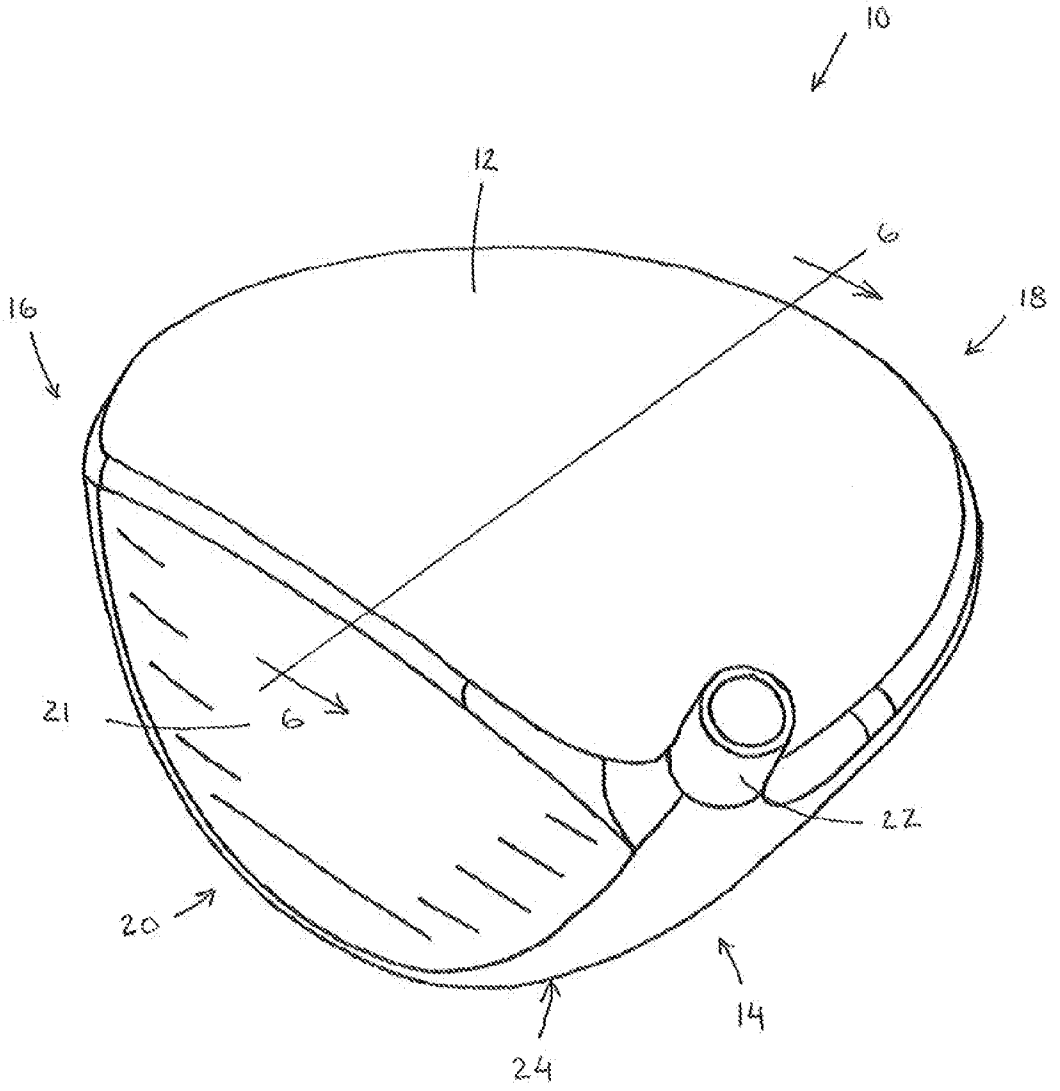
(57) **ABSTRACT**

A golf club head with sound tuning. The golf club head includes a hollow body that defines an interior cavity and a sound tuning feature inside the hollow body. The dimensions and location of the tuning feature are selected to alter the vibration behavior of the golf club head.



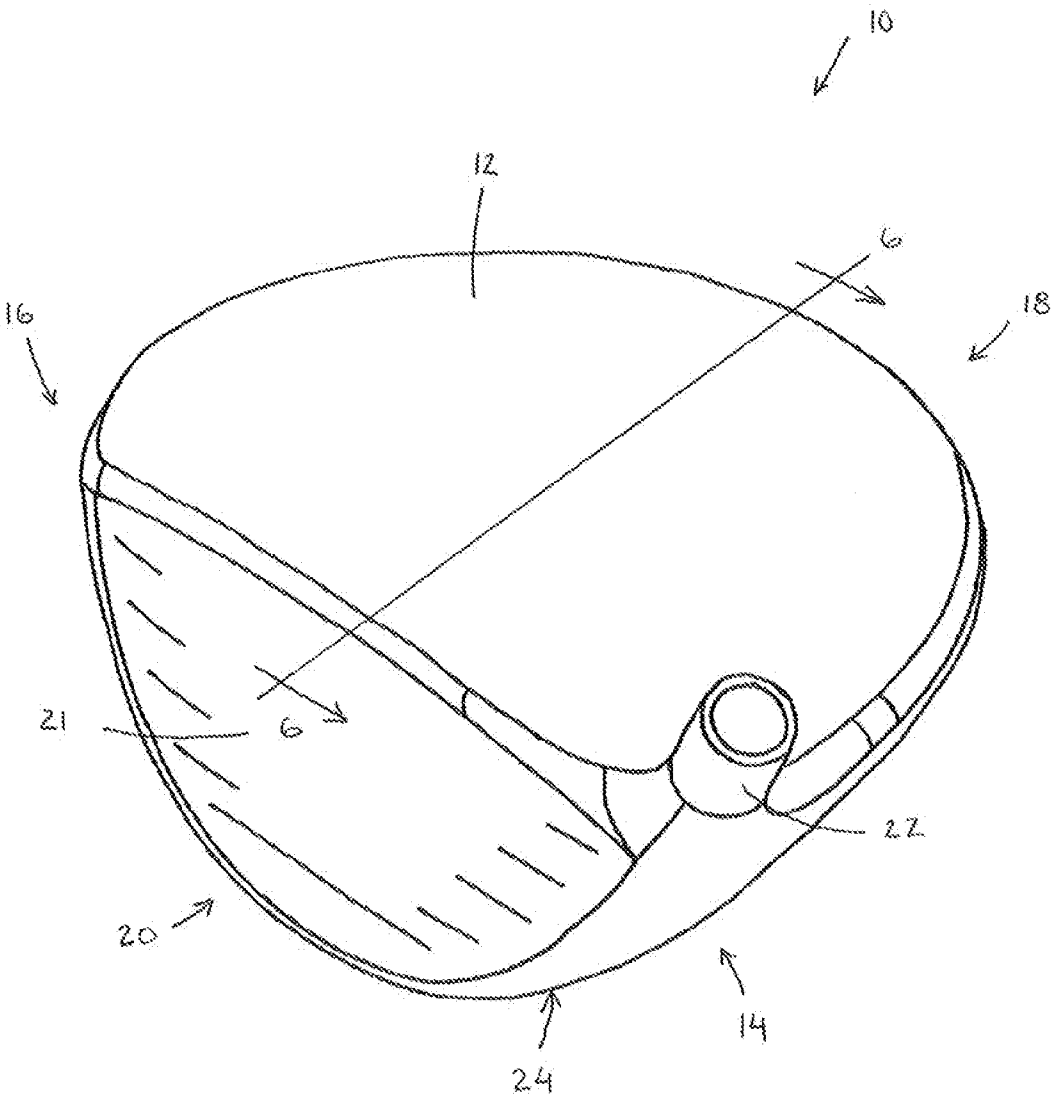


FIG. 1

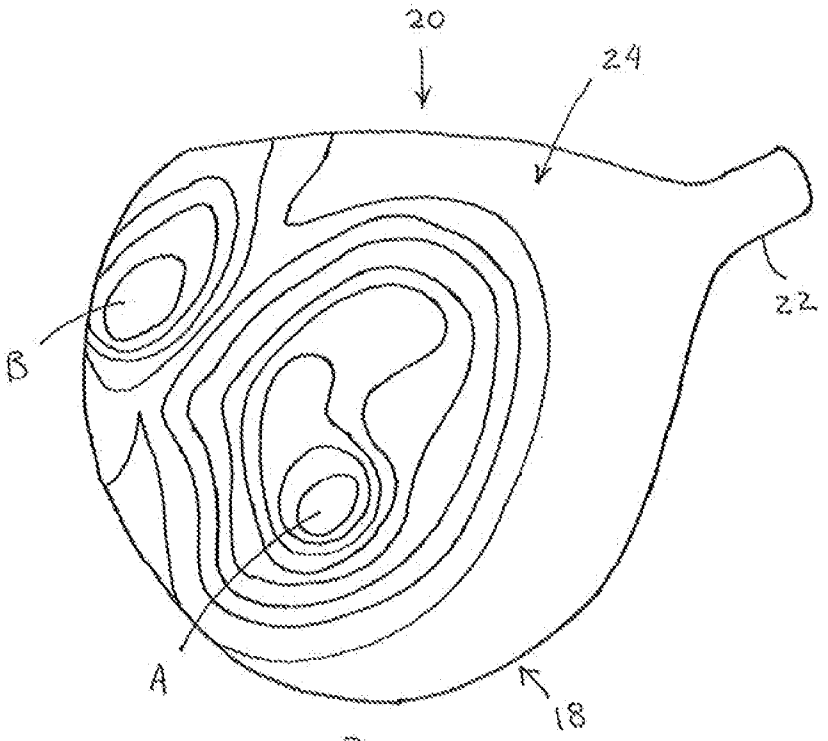


Fig. 2

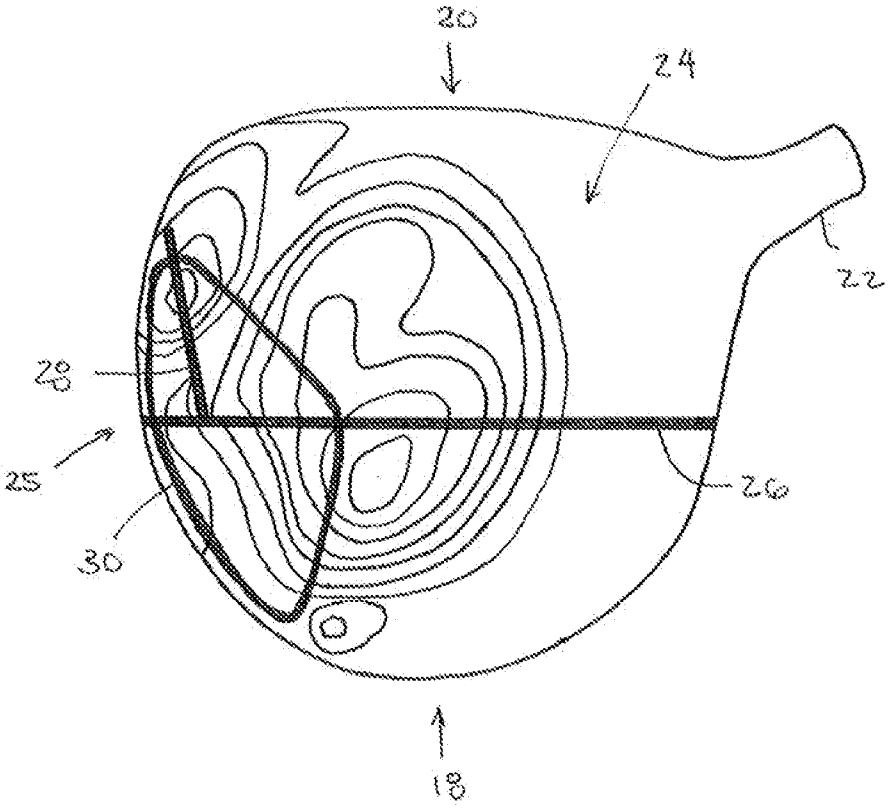


Fig. 3

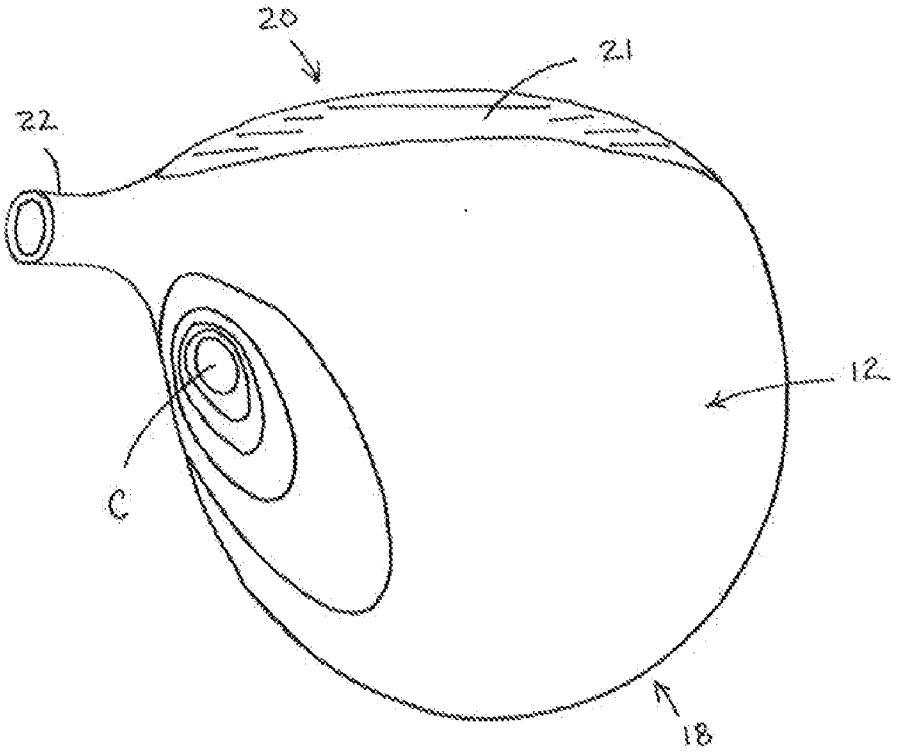


FIG. 4

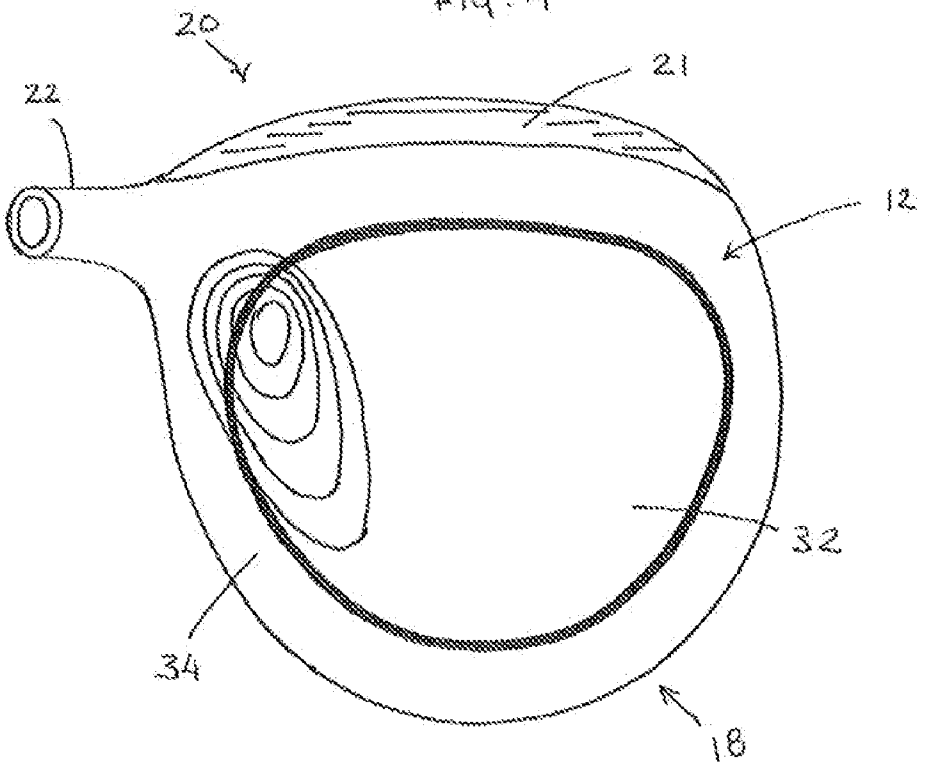


FIG. 5

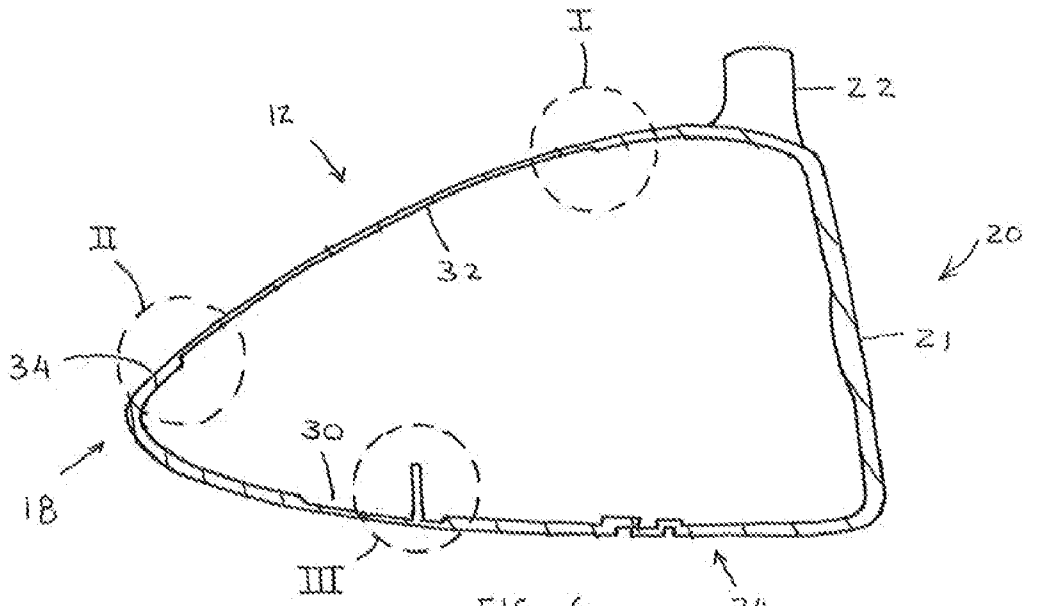
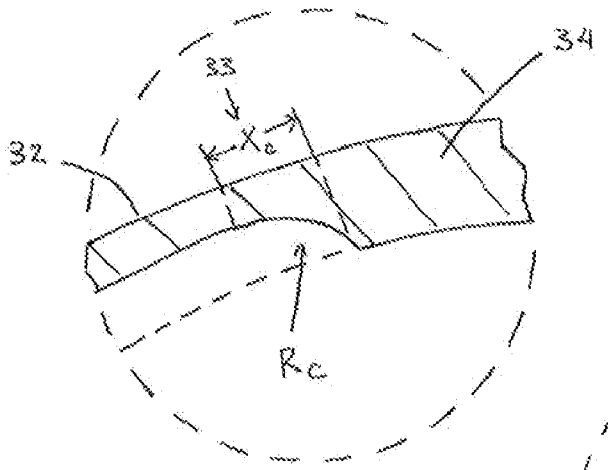
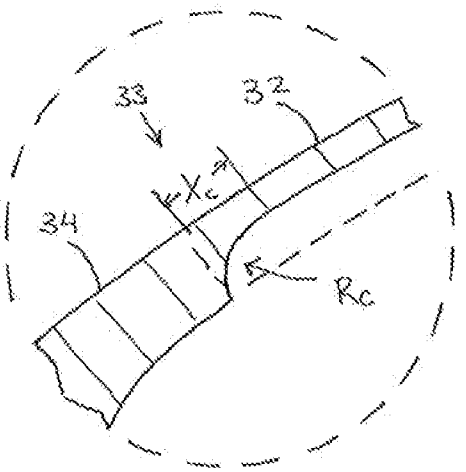


FIG. 6



DETAIL I

FIG. 7



DETAIL II

FIG. 8

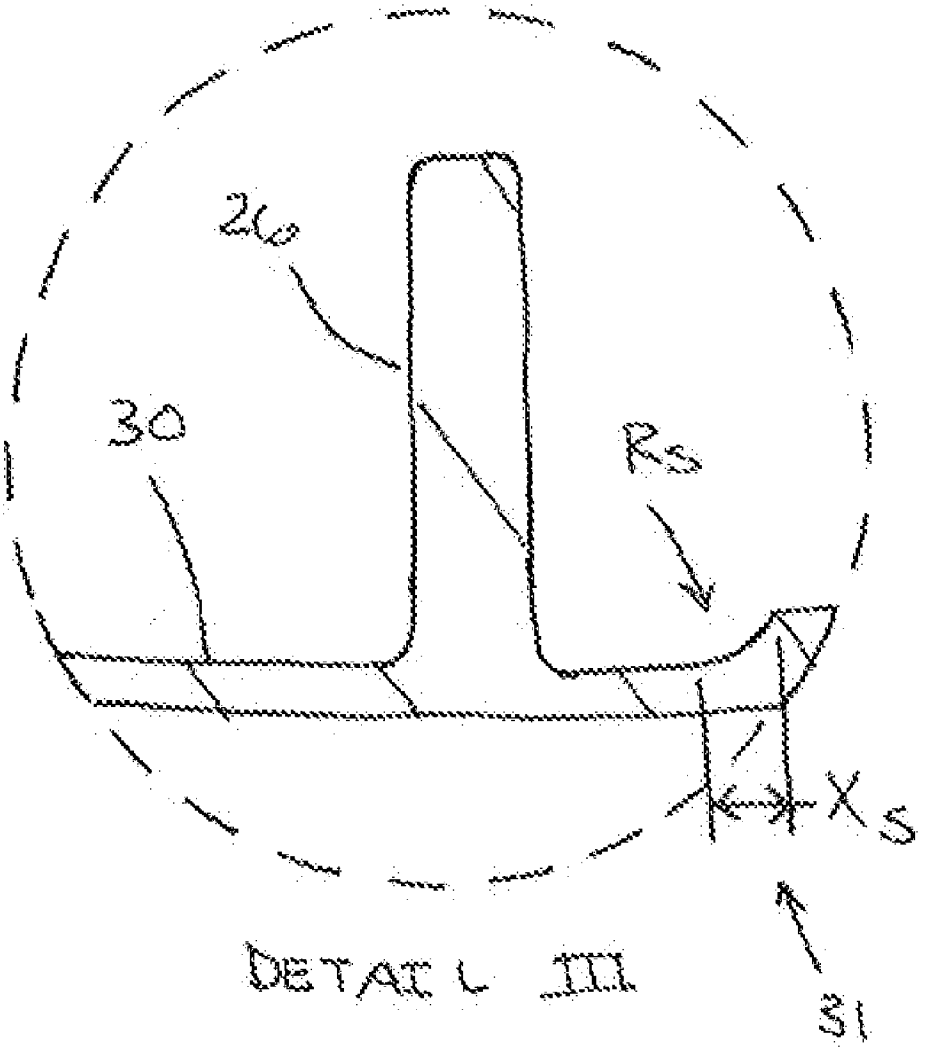


Fig. 9

GOLF CLUB HEAD WITH SOUND TUNING

FIELD OF THE INVENTION

[0001] This invention generally relates to golf club heads, and more specifically to hollow golf club heads including sound tuning features.

BACKGROUND OF THE INVENTION

[0002] As the size of hollow golf club heads has increased, weight distribution has become a major design consideration. In particular, in the quest to design a golf club head of a desired volume while providing discretionary mass, it has become desirable to decrease the wall thicknesses of the portions that do not contribute directly to improved mass properties. Because of the thin wall and the large volumes of the golf club head, large portions of the head act as membranes and vibrate relative to each other. In some instances, the vibration takes place at a relatively low frequency, which results in unappealing sound and feel during impact between the golf club head and a golf ball.

[0003] Previous attempts to tune the sound of the golf club heads have generally included adding material to increase the rigidity of a portion of the club head that exhibits a maximum vibrational displacement caused by impact with a golf ball. For example, ribs are often incorporated into the crown and/or sole of the golf club head to increase the rigidity of those portions. Unfortunately, oftentimes the addition of ribs in the sole and crown reduces the discretionary mass of the club head and forces additional mass to be placed in less ideal locations for manipulating the center of gravity and the moment of inertia of the club head.

[0004] Sound tuning features have been incorporated into hollow bodied golf clubs. One example is described in U.S. Pat. No. 6,852,038 to Yabu for a Golf Club Head and Method of Making the Same. In that example, a hollow body golf club head includes rib-like walls that form the inner surface of the sole and crown. The sound emitted into the hollow cavity due to contact with a golf ball is directed rearward and parted laterally by the ribs. Sound bars are included in some embodiments that are located a small distance behind the club face and extends between the crown and sole. The sound bars are included to further part the sound vibrations.

[0005] Another example is described in U.S. Pat. No. 5,718,641 to Lin for a Golf Club Head that Makes a Sound when Striking the Ball. In that example, the golf club head includes a sound plate that is suspended in the hollow body of the club head that makes a sound and echoes the sound during impact between the club head and a golf ball. One edge of the sound plate is fixed to a wall of the hollow club head and the remaining edges are unattached so that the sound plate is able to vibrate relative to the remainder of the club head.

[0006] It is desirable to provide a golf club that has sound tuning features for altering the sound produced by the golf club head during ball impact.

SUMMARY OF THE INVENTION

[0007] The invention is directed to a golf club head with sound tuning so that the vibration characteristics of the golf club head may be altered to produce a desired sound.

[0008] In an embodiment, a golf club head includes a body including a crown portion and a sole portion and defines an interior cavity. The crown portion includes a first crown thickness area having a first crown thickness, a second crown thickness area having a second crown thickness that is greater than the first crown thickness, and a crown transition. The crown transition defines an interface between the first crown thickness area and the second crown thickness area and is located on the crown portion at a location that exhibits at least 75% of a maximum displacement of a vibration mode having a frequency less than about 3600 Hz. The sole portion includes a first sole thickness area having a first sole thickness, a second sole thickness area having a second sole thickness that is greater than the first sole thickness, and a sole transition. The sole transition defines an interface between the first sole thickness area and the second sole thickness area and is located on the sole portion at a location that exhibits at least 75% of a maximum displacement of a vibration mode having a frequency less than about 4100 Hz.

[0009] In another embodiment, a golf club head includes a body and a truss system. the body includes a crown portion and a sole portion and defines an interior cavity. The truss system comprises a first rib disposed on the sole portion. The sole portion includes a first sole thickness area having a first sole thickness, a second sole thickness area having a second sole thickness that is greater than the first sole thickness, and a sole transition. The sole transition defines an interface between the first sole thickness area and the second sole thickness area and is located on the sole portion at a location that exhibits at least 75% of a maximum displacement of a vibration mode having a frequency less than about 4100 Hz. The first rib intersects the first sole thickness area and the second sole thickness area.

[0010] In a further embodiment, a golf club head includes a body including a crown portion and a sole portion and defines an interior cavity. The crown portion includes a first crown thickness area having a first crown thickness, a second crown thickness area having a second crown thickness that is greater than the first crown thickness, and a crown transition. The crown transition defines an interface between the first crown thickness area and the second crown thickness area and is located on the crown portion at a location that is within about 15 mm of an area of maximum displacement of a vibration mode having a frequency less than about 3600 Hz. The crown transition has a length less than about 2.00 mm and is radiused such that the radius is tangent to the first crown thickness area.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] In the accompanying drawings, which form a part of the specification and are to be read in conjunction therewith and in which like reference numerals are used to indicate like parts in the various views:

[0012] FIG. **1** is a perspective view of a golf club head including sound tuning features according to the present invention;

[0013] FIG. **2** is a bottom schematic view of a golf club head without sound tuning features illustrating the topography of a vibration mode;

[0014] FIG. **3** is another bottom schematic view of the golf club head of FIG. **2** including sound tuning features illustrating the altered topography of the vibration mode;

[0015] FIG. **4** is a top schematic view of a golf club head without sound tuning features illustrating the topography of a vibration mode;

[0016] FIG. **5** is another top schematic view of a golf club head of FIG. **4** including sound tuning features illustrating the altered topography of the vibration mode;

[0017] FIG. **6** is a cross-sectional view of the golf club head of FIG. **1**;

[0018] FIG. **7** is a detail view of the crown portion of the golf club head corresponding to Detail I of FIG. **6**;

[0019] FIG. **8** is another detail view of the crown portion of the golf club head corresponding to Detail II of FIG. **6**; and

[0020] FIG. **9** is a detail view of the sole portion of the golf club head corresponding to Detail III of FIG. **6**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0021] The present invention is directed to a golf club head including sound tuning features. The sound tuning features are included to tailor the sound produced by the golf club head to any desired frequency, amplitude and/or duration.

[0022] Other than in the operating examples, or unless otherwise expressly specified, all of the numerical ranges, amounts, values and percentages such as those for amounts of materials, moments of inertias, center of gravity locations, loft and draft angles, and others in the following portion of the specification may be read as if prefaced by the word "about" even though the term "about" may not expressly appear with the value, amount, or range. Accordingly, unless indicated to the contrary, the numerical parameters set forth in the following specification and attached claims are approximations that may vary depending upon the desired properties sought to be obtained by the present invention. At the very least, and not as an attempt to limit the application of the doctrine of equivalents to the scope of the claims, each numerical parameter should at least be construed in light of the number of reported significant digits and by applying ordinary rounding techniques.

[0023] Notwithstanding that the numerical ranges and parameters setting forth the broad scope of the invention are approximations, the numerical values set forth in the specific examples are reported as precisely as possible. Any numerical value, however, inherently contains certain errors necessarily resulting from the standard deviation found in their respective testing measurements. Furthermore, when numerical ranges of varying scope are set forth herein, it is contemplated that any combination of these values inclusive of the recited values may be used.

[0024] Every golf club produces a distinct sound and feel when it is used to strike a golf ball. The sound and feel are produced by the vibration behavior of the golf club head which is a result of the design of the golf club head. Golf club head designs are analyzed and samples are tested to characterize the vibration characteristics of a particular design in an attempt to determine whether the sound and feel produced by the golf club head will be acceptable to the average golfer. In particular, the frequency values and displacement shapes are determined for the various vibration modes of the club head. It is generally understood that the lower frequency modes, especially those at frequencies below about 3500 Hz, have a tendency to detrimentally affect the sound and feel of a particular golf club head.

[0025] A golf club head including unique sound modifying features will be described with reference to FIG. **1**. Golf club head **10** generally includes a crown portion **12**, a heel portion **14**, a toe portion **16**, a rear portion **18**, a front portion **20**, a hosel **22** and a sole portion **24** that combine to form a generally hollow body having an interior cavity. Front portion **20** includes a striking face **21** for impacting a golf ball. Crown portion **12** extends rearward from front portion **20** and forms a top surface of club head **10**. Heel portion **14** and toe portion **16** form sidewalls of club head **10** and extend generally downward from the edges of crown portion **12** and rearward from side edges of front portion **20**. Rear portion **18** extends between heel portion **14** and toe portion **16** to complete the side wall of club head **10**. Sole portion **24** extends between the lower edges of front portion **20**, heel portion **14**, toe portion **16** and rear portion **18** and generally forms the bottom surface of club head **10**.

[0026] Golf club head **10** includes structural features that tune the sound of the golf club head by manipulating the frequency and displacement shape of the vibration modes. Generally, vibration mode frequencies of less than about 3500 Hz are undesirable, so it is desirable to include such structural features so that the first vibration mode is at a frequency greater than about 3500 Hz. In particular, golf club head **10** includes sound tuning features that both manipulate the vibration modes of the club head while advantageously manipulating the mass of the club head. For example, and as will be discussed in greater detail below, features that add and remove mass from discrete areas of the club head are employed to alter the vibration behavior of the golf club head. The mass is manipulated at areas at or adjacent one or more hot spots in the vibration mode. As used herein, hot spots are localized areas of the structure that exhibit increased displacement at the frequency of the vibration mode. For each vibration mode there is generally a primary hot spot that exhibits maximum displacement over the structure for that vibration mode. Some vibration modes also exhibit secondary and/or tertiary hot spots that exhibit local maximum displacement, but with a displacement magnitude that is less than that of the primary hot spot.

[0027] A golf club having generally constant thickness crown and sole portions was analyzed using finite element analysis (FEA) and the lowest frequency vibration mode (i.e., first mode) was determined to be as illustrated in FIG. **2**. In that instance, the modeled golf club head exhibited a first mode having a frequency of about 2946 Hz. The location of maximum displacement of that vibration mode, i.e., the primary hot spot, was determined to be on the sole of the club head, generally at location A. A secondary hot spot was determined to also be on the sole, toward toe portion **16**, generally at location B. Because the vibration mode included maximum displacement on the sole and because it is generally desired to lower the center of gravity of the golf club head, sound tuning features that add mass were added to sole portion **24** of golf club head **10**.

[0028] In particular, a truss system **25** was added to sole portion **24**. Truss system **25** includes a first rib **26** and a second rib **28**. First rib **26** extends generally across club head **10** in a heel to toe direction. Second rib **28** is generally located adjacent toe portion **16** of club head **10** and extends from first rib **26** generally toward the intersection of toe portion **16** and front portion **20**.

[0029] First and second ribs **26**, **28** were oriented so that they pass through locations on sole portion **24** that are adjacent the primary and secondary hot spots of the analytical vibration mode of FIG. **2**. In particular, first rib **26** extends through a location on sole portion **24** that exhibits a displacement having a magnitude that is at least 75% of the maximum displacement of the primary hot spot. More preferably, first rib **26** extends through a location near the primary hot spot that exhibits a displacement having a magnitude that is at least 85% of the maximum displacement for that hot spot. Second rib **28** similarly extends through a location of sole portion **24** that exhibits a high relative displacement for the locale. In particular, second rib **28** extends through a location that exhibits a displacement magnitude that is at least 75%, more preferably 85%, of the maximum displacement of the secondary hot spot.

[0030] The addition of truss system **25** increased the frequency of the first mode of the analytical model to about 3310 Hz, while only incrementally changing the displacement profile of the vibration mode, as shown in FIG. **3**. Because, even with the addition of truss system **25**, the club head exhibited a first mode frequency still below about 3500 Hz., the thickness of sole portion **24** was increased universally by 0.05 mm. However, that change in thickness increased the frequency of that vibration mode only incrementally.

[0031] Rather than adding additional sound tuning features that locally add mass, such as ribs, to further increase the frequency, as is conventionally done, the thickness of an area of sole portion **24** was reduced and provided the unexpected result of significantly increasing the frequency of the vibration mode. The reduced thickness area **30**, was sized and located so that an edge of area **30** was located adjacent the primary and secondary hot spots, as illustrated in FIG. **3**. In particular, area **30** has a thickness that is approximately 0.05 mm thinner than the surrounding area of sole portion **24**. Preferably, the edge of area **30** extends through locations adjacent the sole hot spots that exhibit at least 75%, more preferably 85%, of the maximum displacement of the nearest hot spot. It should be appreciated that a plurality of reduced thickness areas may be incorporated that are oriented so that an edge is located adjacent a single or multiple hot spots.

[0032] The addition of area **30** to sole portion **24** resulted in an increase in the frequency of that mode to about 4013 Hz, resulting in it no longer being the lowest frequency mode of the golf club head. Instead, after the addition of the sound tuning features in sole portion **24**, the lowest frequency mode of the analytical was determined to be on the crown, at location C, at a frequency of about 3380 Hz, as illustrated in FIG. **4**, in a model having a crown portion with a generally constant thickness.

[0033] A reduced thickness area **32** was incorporated into crown portion **12**, as illustrated in FIG. **5**. Area **32** was sized and located so that an edge of area **32** was located adjacent the primary hot spot of analytical vibration mode. Preferably, the edge of area **32** extends through a location adjacent the crown hot spot that exhibits at least 75%, more preferably 85%, of the maximum displacement of the hot spot. As a result of that change, the frequency of the vibration mode was increased to about 3422 Hz and incrementally altered the displacement shape of the vibration mode. Finally, the crown thickness was increased in both area **32** and the peripheral area **34** by about 0.10 mm. As a result, the frequency of the vibration mode was increased to about 3500 Hz.

[0034] At least portions of the sound tuning features are positioned adjacent hot spots of the analytical vibration modes so that they have a significant impact on the local vibration behavior. As described above, the sound tuning features are preferably located based on vibrational displacement values of analytical models of the club head lacking the features. It should be appreciated, however, that alternatively, the sound tuning features may be positioned so that they are located within a distance of a location exhibiting maximum displacement regardless of the relative magnitude of the displacement. For example, the sound tuning features extend through a location that is at least within 15 mm of the nearest hot spot, or more preferably within 10 mm. Additionally, the reduced thickness portions of crown portion **12** and sole portion **24** may have any shape.

[0035] Referring now to FIGS. **6-9**, the sound tuning features of club head **10** will be described in greater detail. The tuning features include mass increasing features, such as truss system **25**, and mass reducing features, such as reduced thickness areas **30** and **32**.

[0036] In the illustrated embodiments, truss system **25** includes interconnected ribs **26**, **28**. First rib **26** generally extends across club head **10** in a heel to toe direction and is located rearward and below a center of gravity of the golf club head when the club head is in an address position. First rib **26** has a length generally between about 90 mm and about 120 mm, a thickness between about 0.125 mm and about 1.50 mm, and a maximum height in a sole to crown direction of between about 0.25 mm and about 15 mm. Second rib **28** is located generally adjacent toe portion **16** and extends from first rib **26** generally toe-ward and forward. Second rib **28** has a length generally between about 30 mm and about 60 mm, a thickness between about 0.125 mm and about 1.50 mm, and a maximum height in a sole to crown direction of between about 0.25 mm and about 15 mm. It should be appreciated that the truss system may include any number of ribs or pads that are interconnected or discrete components and the features may be constructed as integral cast or forged features or constructed separately and coupled to the club head. It should further be appreciated that the thicknesses of the features forming the truss system are greater than the thick and reduced thickness portions of the crown and sole portions.

[0037] The edges of area **30** and area **32** are configured to provide a relatively drastic change in thickness over a short distance. That configuration provides a stepped interface between the adjacent regions of thickness that extends generally through the hot spots. In particular, area **30** has a thickness that is reduced in comparison to the adjacent area of sole portion **24**. In general, sole portion **24** has a thickness of about 0.60 mm to about 1.00 mm and reduced thickness area **30** has a thickness that is about 85% to about 95% of the thickness of the remainder of sole portion **34**. Preferably, area **32** has a thickness of about 0.50 mm to about 0.95 mm.

[0038] A transition area **31**, shown in FIG. **9**, provides an interface between the thicker area of sole portion **24** and area **30**. A length Xs of transition area **31** is preferably less than about 2.00 mm, and more preferably less than about 1.20 mm. Transition area **31** may have any desired shape. For example, transition area **31** may have any cross-sectional shape, such as curved or linear, i.e., transition area may be generally radiused, as shown, or generally conical. Preferably, transition area **31** is radiused and the radius Rs is about 2.00 mm to about 4.00 mm. Additionally, it is preferable that radius Rs is configured so that it is tangent to the reduced thickness area **30**. It should be further appreciated that the transition area may be stepped rather than including a smooth transition between area **30** and the remainder of sole portion **24**.

[0039] Similarly, area **32** has a thickness that is reduced in comparison to the adjacent peripheral area **34**. Generally, peripheral area **34** has a thickness of about 0.60 mm to about 1.00 mm and reduced thickness area **32** has a thickness that is about 65% to about 80% of the thickness of peripheral area **34**, and more preferably area **32** has a thickness of about 70% to about 75% of the thickness of peripheral area **34**. Preferably, area **32** has a thickness of about 0.40 mm to about 0.80 mm.

[0040] A transition area **33** provides an interface between the thicker peripheral area **34** and area **32**. A length Xc of transition area **33** is preferably less than about 2.00 mm, and more preferably less than about 1.20 mm. Transition area **33** may have any desired shape. For example, transition area **33** may have any cross-sectional shape, such as curved or linear, i.e., transition area may be generally radiused, as shown, or generally conical. Preferably, transition area **33** is radiused and the radius Rc is about 2.00 mm to about 4.00 mm. Additionally, it is preferable that radius Rc is configured so that it is tangent to the reduced thickness area **32**. It should be further

appreciated that the transition area may be stepped rather than including a smooth transition between area **32** and peripheral portion **34**.

[0041] While it is apparent that the illustrative embodiments of the invention disclosed herein fulfill the objectives stated above, it is appreciated that numerous modifications and other embodiments may be devised by those skilled in the art. Elements from one embodiment can be incorporated into other embodiments. Therefore, it will be understood that the appended claims are intended to cover all such modifications and embodiments, which would come within the spirit and scope of the present invention.

We claim:

1. A golf club head, comprising:

a body including a crown portion and a sole portion and defining an interior cavity,

wherein the crown portion includes a first crown thickness area having a first crown thickness, a second crown thickness area having a second crown thickness that is greater than the first crown thickness, and a crown transition defining an interface between the first crown thickness area and the second crown thickness area,

wherein the crown transition is located on the crown portion at a location that exhibits at least 75% of a maximum displacement of a vibration mode having a frequency less than about 3600 Hz.,

wherein the sole portion includes a first sole thickness area having a first sole thickness, a second sole thickness area having a second sole thickness that is greater than the first sole thickness, and a sole transition defining an interface between the first sole thickness area and the second sole thickness area, and

wherein the sole transition is located on the sole portion at a location that exhibits at least 75% of a maximum displacement of a vibration mode having a frequency less than about 4100 Hz.

2. The golf club head of claim **1**, further comprising a truss system, wherein the truss system comprises a first rib that intersects the first sole thickness area and the second sole thickness area.

3. The golf club head of claim **2**, wherein the truss system comprises a second rib that extends from the first rib.

4. The golf club head of claim **3**, wherein the second rib intersects the first sole thickness area and the second sole thickness area.

5. The golf club head of claim **1**, wherein the crown transition has a length less than about 2.00 mm.

6. The golf club head of claim **1**, wherein the crown transition is radiused such that the radius is tangent to the first crown thickness area.

7. The golf club head of claim **1**, wherein the sole transition has a length less than about 2.00 mm.

8. The golf club head of claim **1**, wherein the sole transition is radiused such that the radius is tangent to the first sole thickness area.

9. A golf club head, comprising:

a body including a crown portion and a sole portion and defining an interior cavity; and

a truss system that comprises a first rib disposed on the sole portion,

wherein the sole portion includes a first sole thickness area having a first sole thickness, a second sole thickness area having a second sole thickness that is greater than the first sole thickness, and a sole transition defining an interface between the first sole thickness area and the second sole thickness area,

wherein the sole transition is located on the sole portion at a location that exhibits at least 75% of a maximum displacement of a vibration mode having a frequency less than about 4100 Hz, and

wherein the first rib intersects the first sole thickness area and the second sole thickness area.

10. The golf club head of claim **9**, wherein the truss system comprises a second rib that extends from the first rib.

11. The golf club head of claim **10**, wherein the second rib intersects the first sole thickness area and the second sole thickness area.

12. The golf club head of claim **9**, wherein the sole transition has a length less than about 2.00 mm.

13. The golf club head of claim **9**, wherein the sole transition is radiused such that the radius is tangent to the first sole thickness area.

14. A golf club head, comprising:

a body including a crown portion and a sole portion and defining an interior cavity,

wherein the crown portion includes a first crown thickness area having a first crown thickness, a second crown thickness area having a second crown thickness that is greater than the first crown thickness, and a crown transition defining an interface between the first crown thickness area and the second crown thickness area,

wherein the crown transition is located on the crown portion at a location that is within about 15 mm of an area of maximum displacement of a vibration mode having a frequency less than about 3600 Hz.,

wherein the crown transition has a length less than about 2.00 mm, and

wherein the crown transition is radiused such that the radius is tangent to the first crown thickness area.

15. The golf club head of claim **14**, wherein the sole portion includes a first sole thickness area having a first sole thickness, a second sole thickness area having a second sole thickness that is greater than the first sole thickness, and a sole transition defining an interface between the first sole thickness area and the second sole thickness area.

16. The golf club head of claim **15**, wherein the sole transition portion is located on the sole portion at a location that is within about 15 mm of an area of maximum displacement of a vibration mode having a frequency less than about 4100 Hz.

17. The golf club head of claim **15**, wherein the sole transition has a length less than about 2.00 mm.

18. The golf club head of claim **15**, wherein the sole transition is radiused such that the radius is tangent to the first sole thickness area.

* * * * *