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(54) **IMPROVED IRON TYPE GOLF CLUB HEAD**

(57) An iron golf club head achieving improved performance via a specific Effective Stiffness Area ratio between the boundary of the iron golf club head and the face of the iron golf club head is disclosed. More specifically, the present invention discloses a golf club head

wherein an iron golf club head having a variable face profile into specific iron golf club head chassis resulting in an Effective Stiffness Area Ratio of between about 4.5 to 5.5 and a Coefficient of Restitution value as a function of the above Effective Stiffness Area Ratio.

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**Description****Cross-Reference To Related Applications**

5 [0001] The present application claims the benefit of U.S. Provisional Patent Application Serial No. 60/065,310, filed on August 13, 2020, the disclosure of which is incorporated by reference in its entirety.

**Field of the Invention**

10 [0002] The present invention relates generally to an improved iron type golf club head having a specific ratio of Effective Stiffness Area between the boundary of the iron golf club head and the face of the iron golf club head as well as achieving an improved Coefficient of Restitution. More specifically, the present invention relates to incorporating an iron golf club having a variable face profile into specific iron golf club head chassis resulting in an Effective Stiffness Area Ratio of between about 4.5 to 5.5 and a Coefficient of Restitution value as a function of the above Effective Stiffness Area Ratio.

**Background of the Invention**

15 [0003] Iron golf club heads, similar to their counterpart the wood golf club heads, have benefitted immensely from the technological advancement that the industry has experienced. Although visually, the modern day metalwood looks more different from the persimmon woods when comparing the modern day hollow irons to the traditional mashie or niblick, the technological advancements are probably just game changing.

20 [0004] U.S. Patent No. 4,826,172 to Antonious illustrates one of the earlier advancements in iron golf club head design and technology by teaching a perimeter weighted iron-type golf club head with a recessed or cavity back and a peripheral mass having an improved weight configuration formed of weight members within the cavity. The shift of the mass of the golf club head to the perimeter to create a cavity back allows a golf club head to be more forgiving on off center shots.

25 [0005] U.S. Patent No. 5,362,047 to Shaw et al. illustrates another early example of improving the performance of an iron type golf club head wherein the thickness of the face-piece increasing from the toe to the heel of the head in at least one iron of the set and increasing from the heel to the toe in at least one other iron of the set. Varying the thickness of the face-piece may further improve the performance of a golf club head by reducing material from portions of the striking face that does not require it.

30 [0006] U.S. Patent No. 5,971,868 to Kosmatka illustrates another early attempt to create a contoured back surface of a golf club shown having a surface with varying thicknesses such that regions of the face which experience an approximately similar load due to application of a certain force have an approximately similar thickness to result in a golf club face in which the stress is approximately uniform upon application of a similar force.

35 [0007] U.S. Patent No. 6,200,228 to Takeda provides a golf club with a cavity formed on the rear surface thereof and a back member securely fitted into the cavity, with the body closely contacted each other. This backing allows the increase to the strength of the head that can be improved to enable the thickness of the face to be made thinner.

40 [0008] Most recently, U.S. Patent No. 7,169,057 to Wood et al. discloses an iron golf club head having a hollow interior formed from two different casings, wherein the thickness and hardness of the first casing vary between the long and short iron golf club head.

45 [0009] As the technology improves in the design of iron type golf club heads to gradually develop away from traditional muscle back constructions towards more cavity back and hollow cavity type constructions as illustrated by the patents above, and as striking faces of iron type golf club heads become thinner; an opportunity arises to further improve upon the performance of the striking face of such types of golf club heads.

[0010] Hence, based on the above, there exists a need in the art to develop an improved iron type golf club head that can leverage the new modern day club head chassis design. More specifically, there is tremendous opportunity to design a golf club head having a variable thickness striking face that is a function of the modern day club head chassis, creating an optimal performing golf club head.

**Brief Summary of the Invention**

50 [0011] One aspect of the present invention is an iron golf club head comprising of a frontal portion having a striking face defining a face height ( $H_{\text{Face}}$ ), the striking face further comprising of a substantially planar frontal surface and a non-planar rear surface. The non-planar rear surface of the striking face forming a VFT profile, the VFT profile further comprising a thickened central portion, a transition portion, and a thinned perimeter portion. The thinned perimeter portion defining a face thickness ( $T_{\text{Face}}$ ) and the thickened central portion defining a VFT height ( $H_{\text{VFT}}$ ) and a VFT thickness ( $T_{\text{VFT}}$ ). The iron golf club head also comprising of a body portion attached to a rear of the frontal portion. The iron golf club head defining a boundary height ( $H_{\text{Boundary}}$ ) and a boundary thickness ( $T_{\text{Boundary}}$ ), the iron golf club head

having an ESA Ratio of between about 4.5 and 5.5, the ESA Ratio defined as

$$ESA\ Ratio = \frac{0.5 * T_{Boundary} * H_{Boundary}}{(H_{Face} * T_{Face}) + (0.5 * (T_{VFT} - T_{Face}) * H_{VFT})}$$

and the golf club head has a COR defined by the relationship below;

$$COR \geq 0.0196 (ESA\ Ratio) + 0.7211.$$

**[0012]** In another aspect of the present invention is an iron golf club head comprising of a frontal portion having a striking face defining a face height ( $H_{Face}$ ), the striking face further comprising of a substantially planar frontal surface and a non-planar rear surface. The non-planar rear surface of the striking face forming a VFT profile, the VFT profile further comprising a thickened central portion, a transition portion, and a thinned perimeter portion. The thinned perimeter portion defining a face thickness ( $T_{Face}$ ) and the thickened central portion defining a VFT height ( $H_{VFT}$ ) and a VFT thickness ( $T_{VFT}$ ). The iron golf club head also comprising of a body portion attached to a rear of the frontal portion. The iron golf club head defining a boundary height ( $H_{Boundary}$ ) of between about 35 mm to about 40 mm and a boundary thickness ( $T_{Boundary}$ ) of between about 18 mm to about 24 mm, the iron golf club head having an ESA Ratio of between about 4.5 and 5.5, the ESA Ratio defined as

$$ESA\ Ratio = \frac{0.5 * T_{Boundary} * H_{Boundary}}{(H_{Face} * T_{Face}) + (0.5 * (T_{VFT} - T_{Face}) * H_{VFT})}$$

and the golf club head has a COR defined by the relationship below;

$$COR \geq 0.0196 (ESA\ Ratio) + 0.7211.$$

**[0013]** In another aspect of the present invention is an iron golf club head comprising of a frontal portion having a striking face defining a face height ( $H_{Face}$ ), the striking face further comprising of a substantially planar frontal surface and a non-planar rear surface. The non-planar rear surface of the striking face forming a VFT profile, the VFT profile further comprising a thickened central portion, a transition portion, and a thinned perimeter portion. The thinned perimeter portion defining a face thickness ( $T_{Face}$ ) and the thickened central portion defining a VFT height ( $H_{VFT}$ ) and a VFT thickness ( $T_{VFT}$ ). The iron golf club head also comprising of a body portion attached to a rear of the frontal portion. The iron golf club head defining a boundary height ( $H_{Boundary}$ ) of between about 35 mm to about 40 mm and a boundary thickness ( $T_{Boundary}$ ) of between about 18 mm to about 24 mm. The iron golf club head has an  $ESA_{Boundary}$  of between about 380 mm<sup>2</sup> to about 420 mm<sup>2</sup>, said  $ESA_{Boundary}$  defined as;

$$ESA_{Boundary} = 0.5 * T_{Boundary} * H_{Boundary}.$$

**[0014]** These and other features, aspects and advantages of the present invention will become better understood with reference to the following drawings, description and claims.

### Brief Description Of The Drawings

**[0015]** The foregoing and other features and advantages of the invention will be apparent from the following description of the invention as illustrated in the accompanying drawings. The accompanying drawings, which are incorporated herein and form a part of the specification, further serve to explain the principles of the invention and to enable a person skilled in the pertinent art to make and use the invention.

**FIG. 1** of the accompanying drawings shows a rear view of a golf club head in accordance with an exemplary embodiment of the present invention.

**FIG. 2** of the accompanying drawings shows a rear view of a golf club head in accordance with an exemplary embodiment of the present invention with the support member removed.

**FIG. 3** of the accompanying drawings shows a rear cross-sectional view of a golf club head in accordance with an exemplary embodiment of the present invention.

5 **FIG. 4** of the accompanying drawings shows a cross-sectional view of a golf club head in accordance with an exemplary embodiment of the present invention, taken along cross-sectional line 4-4' shown in **FIG. 3**.

**FIG. 5** of the accompanying drawings shows a cross-sectional view of a golf club head in accordance with an exemplary embodiment of the present invention, taken along cross-sectional line 5-5' shown in **FIG. 3**.

10 **FIG. 6** of the accompanying drawings shows a toe side view of a golf club head in accordance with an exemplary embodiment of the present invention.

**FIG. 7** of the accompanying drawings shows a plot that illustrates a relationship between an ESA Ratio and a COR of a golf club head for the present invention along with prior art golf clubs.

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### Detailed Description Of The Invention

**[0016]** The following detailed description describes the best currently contemplated modes of carrying out the invention. The description is not to be taken in a limiting sense, but is made merely for the purpose of illustrating the general principles of the invention, since the scope of the invention is best defined by the appended claims.

20 **[0017]** Various inventive features are described below and each can be used independently of one another or in combination with other features. However, any single inventive feature may not address any or all of the problems discussed above or may only address one of the problems discussed above. Further, one or more of the problems discussed above may not be fully addressed by any of the features described below.

25 **[0018]** **FIG. 1** of the accompanying drawings shows a rear view of a golf club head **100** in accordance with an exemplary embodiment of the present invention. Golf club head **100** may generally have a toe end **102**, a heel end **104**, a topline **106**, and a sole **108** portion of the golf club head **100** that is common in an iron type golf club heads **100**. In addition to showing these common features and their terminology, **FIG. 1** of the accompanying drawings also shows a hosel **110** portion of the golf club head, to which a shaft is adapted to engage a shaft (not shown).

30 **[0019]** One feature worth noting here is that **FIG. 1** of the accompanying drawing shows a cavity back type golf club head **100**, having a rear opening **112** located at a rear portion of the golf club head **100**. Cavity back type golf club heads **100**, when compared to a traditional blade type golf club head, generally offer more forgiveness due to the shifting of the weight to the perimeter of the golf club head **100**. In addition to providing more forgiveness, cavity back type golf club heads **100** also improves upon the standard blade type golf club head by providing an opportunity to improve the ballspeed of the golf club head **100** by creating a "face mode" that can often yield a higher Coefficient of Restitution (COR).

35 **[0020]** Although these types of cavity back iron type golf club heads have been previously associated with golfers having a higher handicap due to the need of those players for more forgiveness, the modern day golf club have fully embraced this cavity back technology. In fact, the modern day golf player, irrespective of their handicap and even tour players, often incorporates cavity back irons into their bags, especially when it comes to long irons; due to the transformation of these clubs into an extremely playable golf club offering the benefits to all types of players.

40 **[0021]** As more and more effort are devoted into finely engineering these type of designs, these clubs have developed deeper and fuller cavities, even going as far as creating a completely hollowed body construction. In these types of performance driven platforms for iron type golf club head, the trend towards thinner and thinner striking faces generally are required to be paired with stronger and stronger materials. These types of thinner faces in irons, combined with them being made out of stronger materials, especially when incorporated into chassis that yield a higher "face made" such as fuller cavity backs and hollow body constructions, may generally demonstrate higher face deflection, a higher COR, all while accompanied by the undesirable effect of increasing stresses.

45 **[0022]** Hence it can be seen that one of the key objectives of the present invention is to create a high performing iron type golf club head **100** that balances the need of performance by fully taking advantage of the "face mode" generated from chassis that can benefit from such benefits, all while managing the increased stress associated with such a design.

50 **[0023]** In order to accomplish the goal of reducing stresses of these thin faced iron golf club heads having a large unsupported region of the face that creates a "face mode", the present invention utilizes a Variable Face Thickness (VFT) profile **114** at the back surface of the striking face **111**. The VFT profile **114** may generally be comprised out of a thickened central portion, a transition region, and a thinned perimeter. The thickened central portion, in this current exemplary embodiment of the present invention, may generally have a constant thickness. The thinned perimeter, on the other hand, although generally also has a constant thickness, may also have a taper as well. The back view of the golf club head **100** shown in **FIG. 1** is shown as a finished product, and has a support member **120** contacting the rear of the VFT profile **114**. In order to better illustrate the VFT profile **114**, **FIG. 2** of the accompanying drawings is provided

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where the support member **120** is removed.

**[0024]** FIG. 2 of the accompanying drawings shows a rear view of a golf club head **200** in accordance with an exemplary embodiment of the present invention with the support member (shown as **120** in FIG. 1 removed) for a clearer illustration of the VFT profile **214**. At first glance, one can immediately see that the VFT profile **214** further comprises of two sub-components that was previously discussed. More specifically, the VFT profile **214** further comprises a thickened central portion **214a** and a transition portion **214b**.

**[0025]** The thinned perimeter portion **216** of the striking face **111** (shown previously in FIG. 1) shown in FIG. 2 can also be separated into three sub-components, such as a heel perimeter portion **216a** located near a heel **204** of a golf club head **200**, toe perimeter portion **216c** located near a toe **202** of a golf club head **200**, and a central perimeter portion **216b** juxtaposed between the heel perimeter portion **216a** and the toe perimeter portion **216c**. In a preferred embodiment of the present invention, the entirety of the perimeter portion **216a**, **216b**, and **216c** could be constantly tapered from the toe perimeter portion **216c** towards the heel perimeter portion **216a**, with the toe perimeter portion **216c** being the thickest and the heel perimeter portion **216a** being the thinnest. However, in an alternative embodiment of the present invention, this tapering need not be constant, and can only exist in the toe perimeter portion **216c**, the central perimeter portion **216b**, the heel perimeter portion **216a**, or any combination thereof, so long as the toe-ward most portion is thicker than the heel-ward most portion. Alternatively speaking, it can be said that the toe portion of said perimeter portion is thicker than a heel portion of said perimeter portion. In a further alternative embodiment of the present invention, the entirety of the perimeter portion **216a**, **216b**, and **216c** can be all of the same thickness without departing from the scope and content of the present invention.

**[0026]** Hence, looking at the entirety of the striking face **211**, it can be said that the golf club head **200** has a variable thickness profile **214** with two sub-components; a thickened central portion **214a** having a highest thickness, and a transition portion **214b** having a variable thickness that transitions from the thickened central portion **214a** to the perimeter portions **216a**, **216b**, and **216c**. The perimeter portions **216a**, **216b**, and **216c**, in a preferred embodiment, may generally be thicker on the toe than the heel, with a gradual tapering throughout. In order to accomplish this, the heel perimeter portion **216a** could be flat or tapering, the central perimeter portion **216b** may be flat or tapering, and the toe perimeter portion **216c** could be flat or tapering; or any combination thereof could be used all without departing from the scope and content of the present invention. Finally, in an alternative embodiment of the present invention, as previously mentioned, the entirety of the perimeter portions **216a**, **216b**, and **216c** could be constant also without departing from the scope and content of the present invention.

**[0027]** In order to provide a clearer view of the various dimensions of the variable thickness profile **214** profile, a cutaway view of the golf club head **200** is provided wherein the rear portion of the golf club head **200** is removed. FIG. 3 of the accompanying drawings shows an enlarged cutaway view of a golf club head **300** in accordance with an exemplary embodiment of the present invention, allowing certain additional features to be highlighted.

**[0028]** First off, we can see that in this cutaway view of the golf club head **300** shown in FIG. 3, the variable thickness profile **314** can be seen more clearly. The thickened central portion **314a** shown in FIG. 3 allows its dimension to be identified, as this dimension is critical to the performance of the golf club head **300** itself. In this embodiment of the present invention, the thickened central portion **314a** may have a width  $W_{VFT}$  of between about 15 mm to about 35 mm, more preferably between about 20 mm to about 30 mm, and most preferably about 26 mm. The thickened central portion **314a** may have a height  $H_{VFT}$  of between about 10 mm to about 27 mm, more preferably between about 15 mm to about 22 mm, and most preferably about 18 mm. FIG. 3 also shows a center point **333** of the thickened central portion **314a**.

**[0029]** In addition to the dimension of the thickened central portion **314a**, FIG. 3 of the accompanying drawings also shows a distance  $H_{Face}$  that corresponds with the height of the striking face **311** at the center of the face. The height of the striking face **311**, as represented by distance  $H_{Face}$  may generally be between about 50 mm to about 54 mm, more preferably between about 51 mm to about 53 mm, and most preferably about 52 mm.

**[0030]** Finally, FIG. 3 of the accompanying drawings also identifies two specific points within the thickened central portion **314a**, a location of maximum stress **332** and a location of maximum deflection **334**. It is critical for the present invention that the thickened central portion **314a** to encompass both the location of maximum stress **332** and the location of maximum deflection **334**, as these locations generally outline the locations that generally experience the highest stress, and could benefit from the increased material thickness associated with the thickened central portion **314a**. The location of maximum deflection **334**, as referred to in this embodiment of the present invention, refers generally to a point that coincides with the hotspot of the face, which coincidentally, is also the geometric center of the face of the golf club head **300**. The location of maximum deflection **334**, can generally be determined by making physical measurements of the geometric center of the face of the golf club head **300**. Alternatively, this location can be determined via a modal analysis to try and capture the location of the maximum deflection based on a prediction of the actual deflection the golf club head **300** is expected to experience upon impact with a golf ball. The location of maximum stress **332**, on the other hand, occurs generally at a location that is directly behind the impact location with a golf ball. This location, is generally slightly heelward of the location of maximum deflection **334** and slightly lower on the face than the location of the maximum deflection **334**. This location is generally estimated to be at the central point of the scoreline

in a heel to toe direction, at a location that is about 15 mm up from the leading edge of the golf club head **300**. Once again, it is worth repeating here that the thickened central portion **314a** encompassing both the location of maximum stress **332** and the location of maximum deflection **334** is critical to the present invention, as both of these locations experience higher stress than the remainder of the face when impacting a golf ball, and the thickened central portion's **314a** increase thickness really help with the durability of the golf club head **300**.

**[0031]** FIG. 4 of the accompanying drawings shows a cross-sectional view of a golf club head **300** shown in FIG. 3, as illustrated by cross-sectional lines 4-4'. This cross-sectional view allows the thickness of the striking face **411** to be shown more clearly. In this view, we can see that the striking face **411** has a substantially planar frontal surface and a non-planar rear surface creating the VFT profile. More specifically, the VFT profile, as previously discussed, is comprised out of a thickened central portion **414a** that transitions into a perimeter portion **416c**. The thickened central portion **414a** in accordance with this exemplary embodiment of the present invention may generally have a thickness  $T_{VFT}$  of between about 1.9 mm and about 2.3 mm, more preferably between about 2.0 mm and about 2.2 mm, and most preferably about 2.1 mm. Since this cross-sectional view of the golf club head **400** is taken along a cross-sectional line 4-4' shown in FIG. 3 that is located at the central portion of the golf club head **400**, the perimeter portion thickness shown here is actually the central perimeter portion **416b** thickness. The central perimeter portion **416b**, located both above and beneath the thickened central portion **414a**, may generally have a thickness  $T_{Face}$  of between about 1.6 mm and about 2.0 mm, more preferably between about 1.7 mm and about 1.9 mm, most preferably about 1.8 mm. The transition region **414b**, also located above and beneath the thickened central portion **414a**, gradually tapers in thickness from the thickened central portion **414a** towards the central perimeter portion **416b** thickness.

**[0032]** FIG. 5 of the accompanying drawings shows a cross-sectional view of a golf club head **500** taken along cross-sectional line 5-5' shown in FIG. 3. This cross-sectional line is taken along a toe portion of the golf club head **300** at a point that yields the highest face height value. Thus, we can see that  $H_{Face}$ , although previously described in FIG. 3, along this cross-sectional view, doesn't convey all the information required in FIG. 3 to provide an accurate measurement because it lacked a reference point from the side view. More specifically, the face height distance  $H_{Face}$  is measured along the loft of the golf club head **500** that is parallel to the striking face, not parallel to the ground plane as FIG. 3 seems to suggest initially. Getting an accurate definition for measuring the face height distance  $H_{Face}$  is an important variable in determining an Effective Boundary Stiffness Area (ESA) of the face ( $ESA_{Face}$ ), which is critical to the present invention.  $ESA_{Face}$ , in accordance with the present invention, is defined by Equation (1) below:

$$ESA_{Face} = (H_{Face} * T_{Face}) + (0.5 * (T_{VFT} - T_{Face}) * H_{VFT}) \quad \text{Eq. (1)}$$

Based on Equation (1) above, a golf club head **500** in accordance with an exemplary embodiment of the present invention may have an  $ESA_{Face}$  of between about 80 mm<sup>2</sup> to about 110 mm<sup>2</sup>, more preferably between about 90 mm<sup>2</sup> to about 100 mm<sup>2</sup>, most preferably about 95 mm<sup>2</sup>.

**[0033]** FIG. 6 of the accompanying drawings shows a toe side view of a golf club head **600** in accordance with an exemplary embodiment of the present invention, allowing the overall size of the golf club head **600** to be shown. FIG. 6 goes further into identifying additional dimensions and measurements that will be important in determining an ESA of the boundary ( $ESA_{Boundary}$ ). Ultimately, a golf club in accordance with the present invention will have a specific  $ESA_{Face}$  to  $ESA_{Boundary}$  Ratio. First and foremost, FIG. 6 of the accompanying drawings shows the golf club having a height of the chassis, defined as  $H_{Boundary}$ , measuring the top of the golf club head **600** to the bottom of the club head **600** in an address position. Golf club head **600** may generally have a  $H_{Boundary}$  of between about 35 mm to about 40 mm, more preferably between about 36 mm to about 39 mm, and most preferably between about 37 mm to about 38 mm. Once the  $H_{Boundary}$  is determined, a geometric center of the face **634** may be determined, at least up the face, by dividing the  $H_{Boundary}$  distance by 2. Once that center of the face **634** is determined, a thickness of the chassis boundary,  $T_{Boundary}$  may be determined as measuring rearward from the center of the face **634** at an angle that is perpendicular to the angle of the striking face itself.  $T_{Boundary}$ , as shown in this current exemplary embodiment may generally be between about 18 mm to about 24 mm, more preferably between about 19 mm to about 23 mm, more preferably between about 20 mm to about 22 mm.

**[0034]** Once the values for  $H_{Boundary}$  and  $T_{Boundary}$  have been established, an  $ESA_{Boundary}$  can be calculated based on Equation (2) below:

$$ESA_{Boundary} = 0.5 * T_{Boundary} * H_{Boundary} \quad \text{Eq. (2)}$$

Based on Equation (2) above, a golf club head **600** in accordance with an exemplary embodiment of the present invention may have an  $ESA_{Boundary}$  of between about 380 mm<sup>2</sup> to about 420 mm<sup>2</sup>, more preferably between about 390 mm<sup>2</sup> to about 410 mm<sup>2</sup>, most preferably about 400 mm<sup>2</sup>.

**[0035]** Now that the  $ESA_{Face}$  and the  $ESA_{Boundary}$  have been defined and established, one can create a ratio between the two numbers to create an ESA Ratio, which denotes one of the critical features of the present invention describing one way to quantify that the golf club head **600** will experience a face mode. The ESA Ratio is defined by Equation (3) below:

$$ESA\ Ratio = \frac{ESA\ Boundary}{ESA\ Face} \quad Eq.\ (3)$$

A golf club head in accordance with the present invention may generally have an ESA Ratio of between about 4.5 to about 5.5, more preferably between about 4.7 to about 5.3, more preferably between about 4.8 and about 5.2. Alternatively, Equation (3) can be combined with Equations (1) and (2) to create a more detailed definition of the ESA Ratio, as shown in Equation (4) below:

$$ESA\ Ratio = \frac{0.5 * T_{Boundary} * H_{Boundary}}{(H_{Face} * T_{Face}) + (0.5 * (T_{VFT} - T_{Face}) * H_{VFT})} \quad Eq.\ (4)$$

**[0036]** **FIG. 7** of the accompanying drawings show a plot that illustrates the ESA Ratio vs. Coefficient of Restitution (COR) of several embodiments of the present invention as well as four different prior art clubs. In **FIG. 7** shown here, the ESA Ratio is shown along the X-Axis, and the COR of the golf club head is shown along the Y-Axis. Focusing three of the prior art golf club heads, we can see these three prior art data points do not have ESA Ratio values between 4.5 and 5.5; and have ESA Ratio values of about 3.4, about 4.25, and about 4.0. The other fourth prior art data point, while does have an ESA Ratio value between 4.5 and 5.5, does not have achieve a high enough COR of above 0.828 for the given ESA Ratio value. In order to capture the region of increased performance achieved by the present invention, an equation is provided in **FIG. 7**, wherein  $y \geq 0.0196x + 0.7211$  to help further narrow the range of performance values previously unachieved within the ESA Ratio values described previously. To put the above relationship into the context of the values relevant to our current conversation, Equation (5) is provided below:

$$COR \geq 0.0196 (ESA\ Ratio) + 0.7211 \quad Eq.\ (5)$$

**[0037]** Combining this discussion, it can be said that the current inventive golf club head has an ESA Ratio of between about 4.5 and about 5.5, and a COR value that is greater than  $0.0196 (ESA\ Ratio) + 0.7211$ .

**[0038]** Finally, any discussion on thin faced iron here would not be complete without recognizing the importance of durability. Durability of a golf club is generally related to the amount of stress it experiences upon impact with a golf ball. Typically, in an iron type golf club head that is made out of steel, the durability of the golf club suffers significantly at any number greater than about 2.2 GPa. Alternatively speaking, it can be said that a golf club head in accordance with the present invention, in order to have a stress number less than about 2.2 GPa, more preferably less than about 2.1 GPa, and most preferably less than about 2.0 GPa.

**[0039]** Other than in the operating example, or unless otherwise expressly specified, all of the numerical ranges, amounts, values and percentages such as those for amounts of materials, moment of inertias, center of gravity locations, loft, draft angles, various performance ratios, and others in the aforementioned portions of the specification may be read as if prefaced by the word "about" even though the term "about" may not expressly appear in the value, amount, or range. Accordingly, unless indicated to the contrary, the numerical parameters set forth in the above 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.

**[0040]** 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.

**[0041]** It should be understood, of course, that the foregoing relates to exemplary embodiments of the present invention and that modifications may be made without departing from the spirit and scope of the invention as set forth in the following claims.

Claims

1. An iron golf club head comprising:

5 a frontal portion having a striking face defining a face height ( $H_{Face}$ ),  
 said striking face further comprising a substantially planar frontal surface and a non-planar rear surface,  
 said non-planar rear surface of said striking face forming a VFT profile, said VFT profile further comprising  
 10 a thickened central portion, a transition portion, and a thinned perimeter portion,  
 said thinned perimeter portion defining a face thickness ( $T_{Face}$ ),  
 said thickened central portion defining a VFT height ( $H_{VFT}$ ) and a VFT thickness ( $T_{VFT}$ ),  
 a body portion attached to a rear of said frontal portion,  
 said iron golf club head defining a boundary height ( $H_{Boundary}$ ) and a boundary thickness ( $T_{Boundary}$ ),  
 15 said iron golf club head having an ESA Ratio of between about 4.5 and 5.5, said ESA Ratio defined as,

$$ESA\ Ratio = \frac{0.5 * T_{Boundary} * H_{Boundary}}{(H_{Face} * T_{Face}) + (0.5 * (T_{VFT} - T_{Face}) * H_{VFT})}$$

20 and said golf club head has a COR defined by the relationship below;

$$COR \geq 0.0196 (ESA\ Ratio) + 0.7211.$$

- 25 2. The iron golf club head of claim 1, wherein said iron golf club head has an  $ESA_{Face}$  of between about 80 mm<sup>2</sup> to about 110 mm<sup>2</sup>, said  $ESA_{Face}$  defined as,

$$30 \quad ESA_{Face} = (H_{Face} * T_{Face}) + (0.5 * (T_{VFT} - T_{Face}) * H_{VFT}).$$

3. The iron golf club head of claim 2, wherein said  $ESA_{Face}$  is between about 90 mm<sup>2</sup> to about 100 mm<sup>2</sup>.  
 4. The iron golf club head of claim 3, wherein said  $ESA_{Face}$  is about 95 mm<sup>2</sup>.  
 35 5. The iron golf club head of claim 2, wherein said iron golf club head has an  $ESA_{Boundary}$  of between about 380 mm<sup>2</sup> to about 420 mm<sup>2</sup>, said  $ESA_{Boundary}$  defined as.

$$40 \quad ESA_{Boundary} = 0.5 * T_{Boundary} * H_{Boundary}.$$

6. The iron golf club head of claim 5, wherein said  $ESA_{Boundary}$  is between about 390 mm<sup>2</sup> to about 410 mm<sup>2</sup>.  
 7. The iron golf club head of claim 6, wherein said  $ESA_{Boundary}$  is about 400 mm<sup>2</sup>.  
 45 8. The iron golf club head of claim 1, wherein said thickened central portion has said VFT thickness ( $T_{VFT}$ ) of between about 1.9 mm and about 2.3 mm, said VFT height ( $H_{VFT}$ ) of between about 10 mm to about 27 mm, and a VFT width ( $W_{VFT}$ ) of between about 15 mm to about 35 mm.  
 9. The iron golf club head of claim 8, wherein said VFT thickness ( $T_{VFT}$ ) is between about 2.0 mm and about 2.2 mm, said VFT height ( $H_{VFT}$ ) is between about 15 mm to about 22 mm, and said VFT width ( $W_{VFT}$ ) is between about 20 mm to about 30 mm.  
 50 10. The iron golf club head of claim 9, wherein said VFT thickness ( $T_{VFT}$ ) is about 2.1 mm, said VFT height ( $H_{VFT}$ ) is about 18 mm, and said VFT width ( $W_{VFT}$ ) about 26 mm.  
 55 11. The iron golf club head of claim 1, wherein the boundary height ( $H_{Boundary}$ ) is between about 35 mm to about 40 mm and the boundary thickness ( $T_{Boundary}$ ) is between about 18 mm to about 24 mm.

12. The iron golf club head of claim 11, wherein said boundary height ( $H_{\text{Boundary}}$ ) is between about 36 mm to about 39 mm and said boundary thickness ( $T_{\text{Boundary}}$ ) is between about 19 mm to about 23 mm, optionally wherein said boundary height ( $H_{\text{Boundary}}$ ) is between about 37 mm to about 38 mm and said boundary thickness ( $T_{\text{Boundary}}$ ) is between about 20 mm to about 22 mm.

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13. An iron golf club head comprising:

a frontal portion having a striking face defining a face height ( $H_{\text{Face}}$ ),

10 said striking face further comprising a substantially planar frontal surface and a non-planar rear surface, said non-planar rear surface of said striking face forming a VFT profile, said VFT profile further comprising a thickened central portion, a transition portion, and a thinned perimeter portion, said thinned perimeter portion defining a face thickness ( $T_{\text{Face}}$ ), said thickened central portion defining a VFT height ( $H_{\text{VFT}}$ ) and a VFT thickness ( $T_{\text{VFT}}$ ),

15 a body portion attached to a rear of said frontal portion, said iron golf club head defining a boundary height ( $H_{\text{Boundary}}$ ) of between about 35 mm to about 40 mm and a boundary thickness ( $T_{\text{Boundary}}$ ) of between about 18 mm to about 24 mm, wherein said iron golf club head has an  $ESA_{\text{Boundary}}$  of between about 380 mm<sup>2</sup> to about 420 mm<sup>2</sup>, said  $ESA_{\text{Boundary}}$  defined as.

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$$ESA_{\text{Boundary}} = 0.5 * T_{\text{Boundary}} * H_{\text{Boundary}}$$

25 14. The iron golf club head of claim 13, wherein said  $ESA_{\text{Boundary}}$  is between about 390 mm<sup>2</sup> to about 410 mm<sup>2</sup>, optionally wherein said  $ESA_{\text{Boundary}}$  is about 400 mm<sup>2</sup>.

30 15. The iron golf club head of claim 14, wherein said thickened central portion has said VFT thickness ( $T_{\text{VFT}}$ ) of between about 1.9 mm and about 2.3 mm, said VFT height ( $H_{\text{VFT}}$ ) of between about 10 mm to about 27 mm, and a VFT width ( $W_{\text{VFT}}$ ) of between about 15 mm to about 35 mm.

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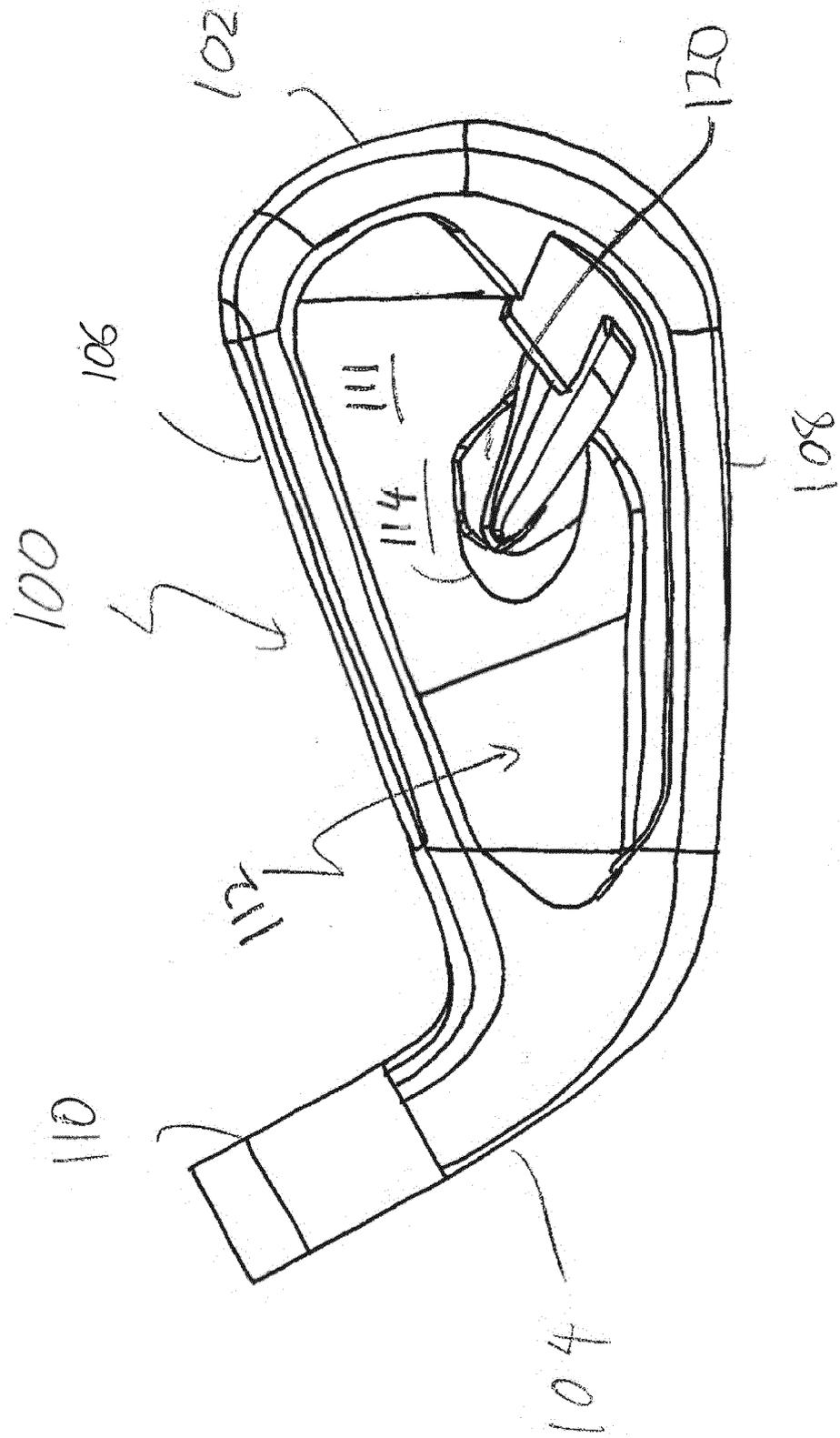


FIG. 1

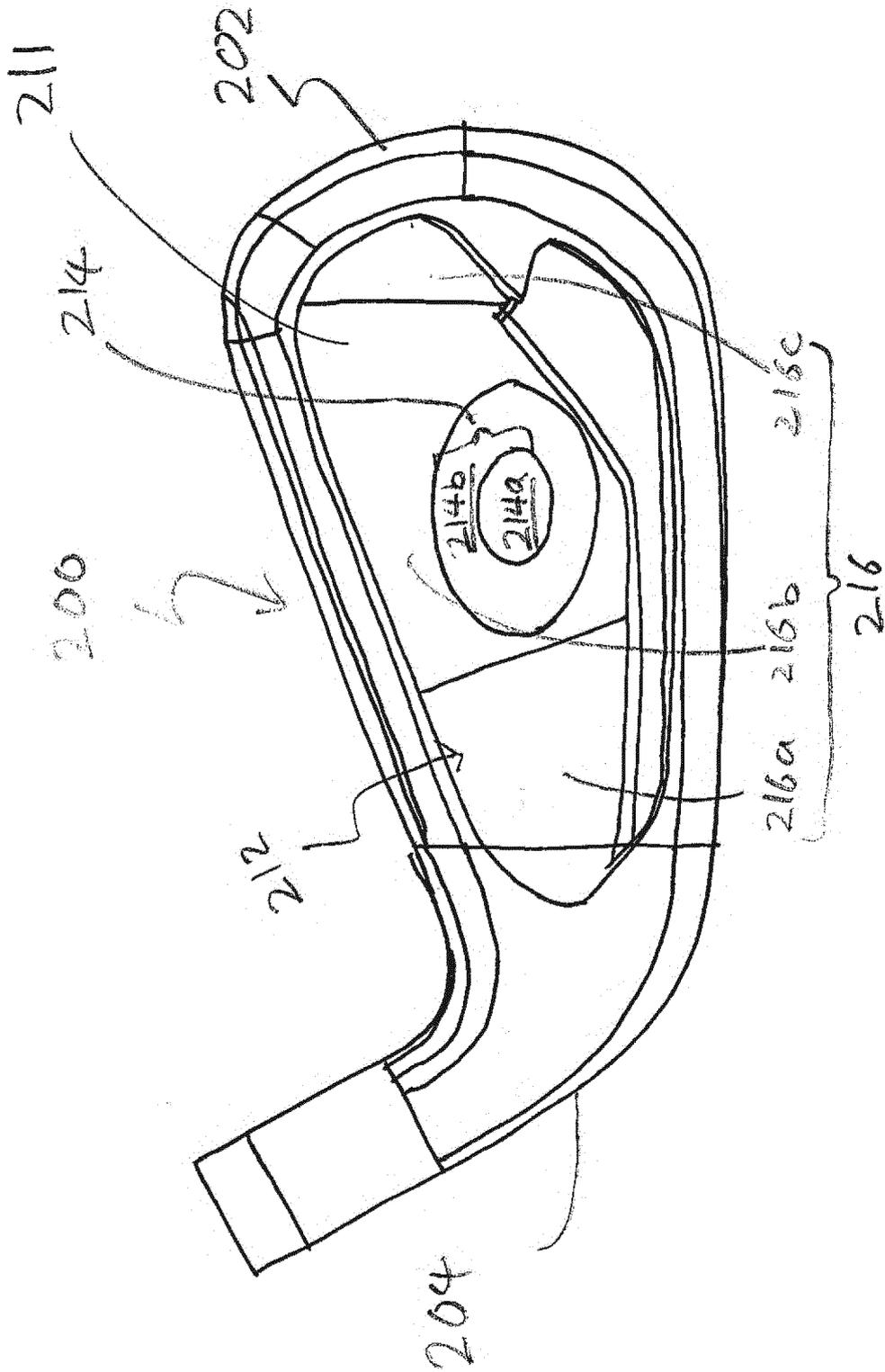


FIG. 2

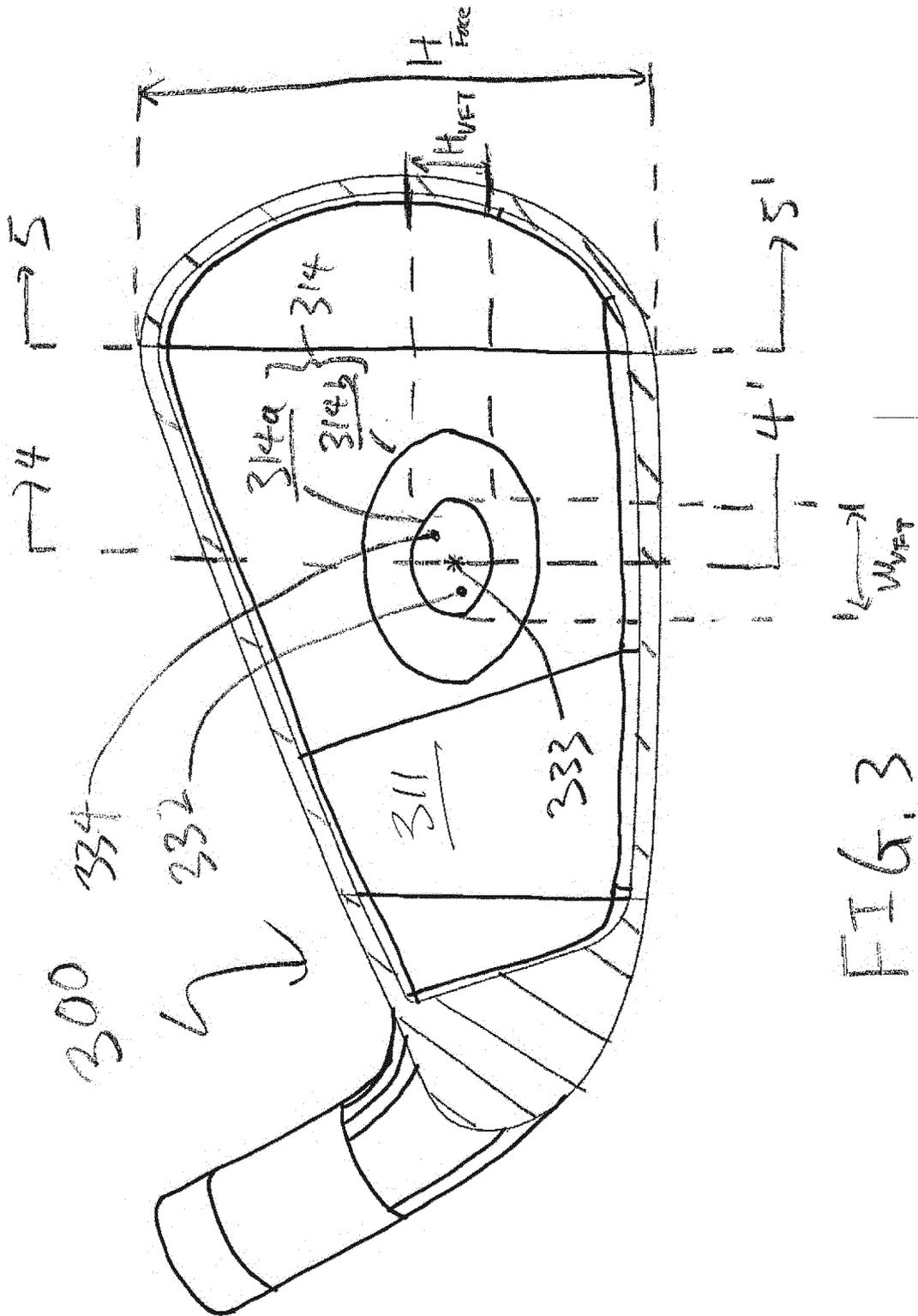


FIG. 3

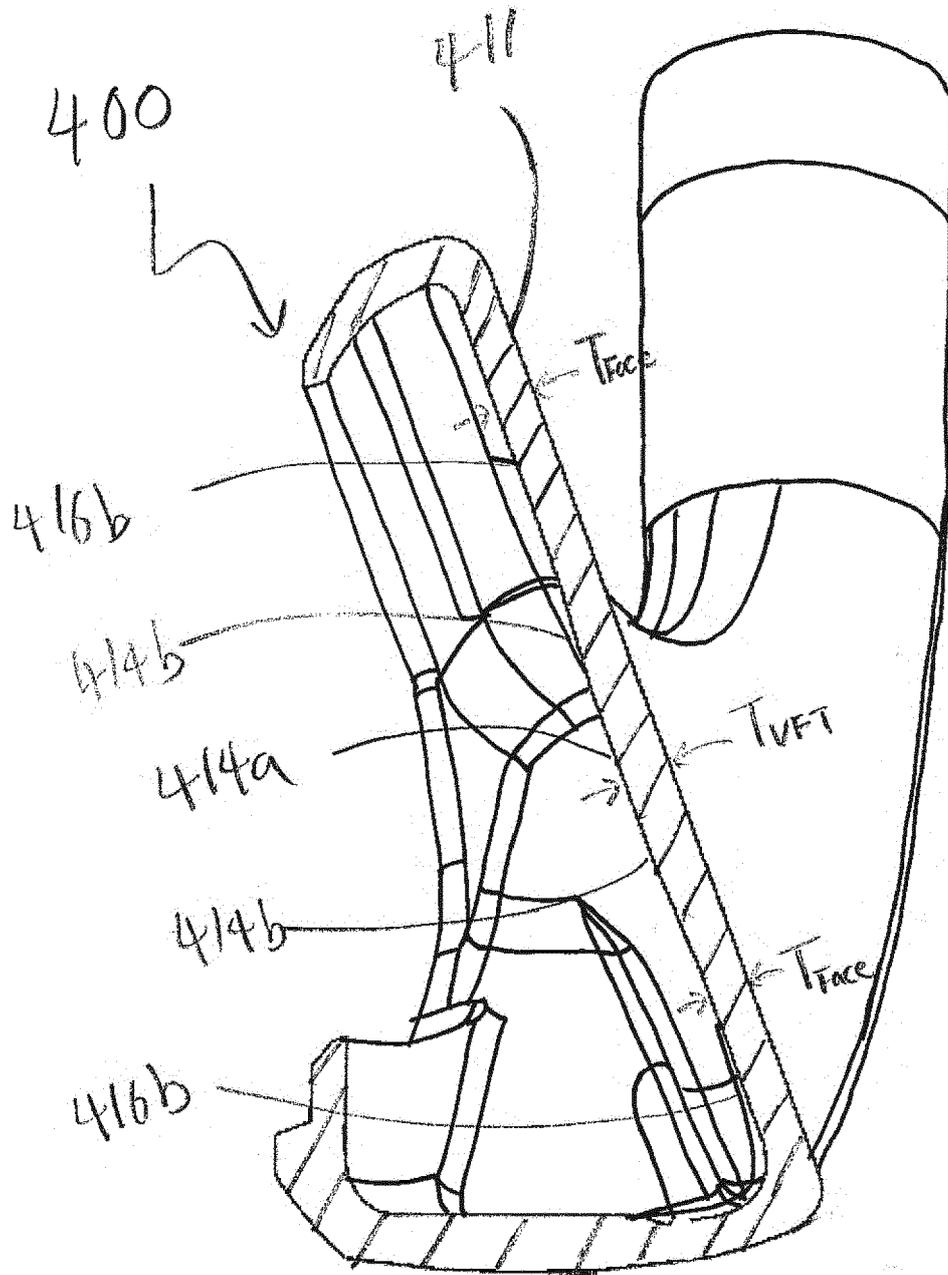


FIG. 4

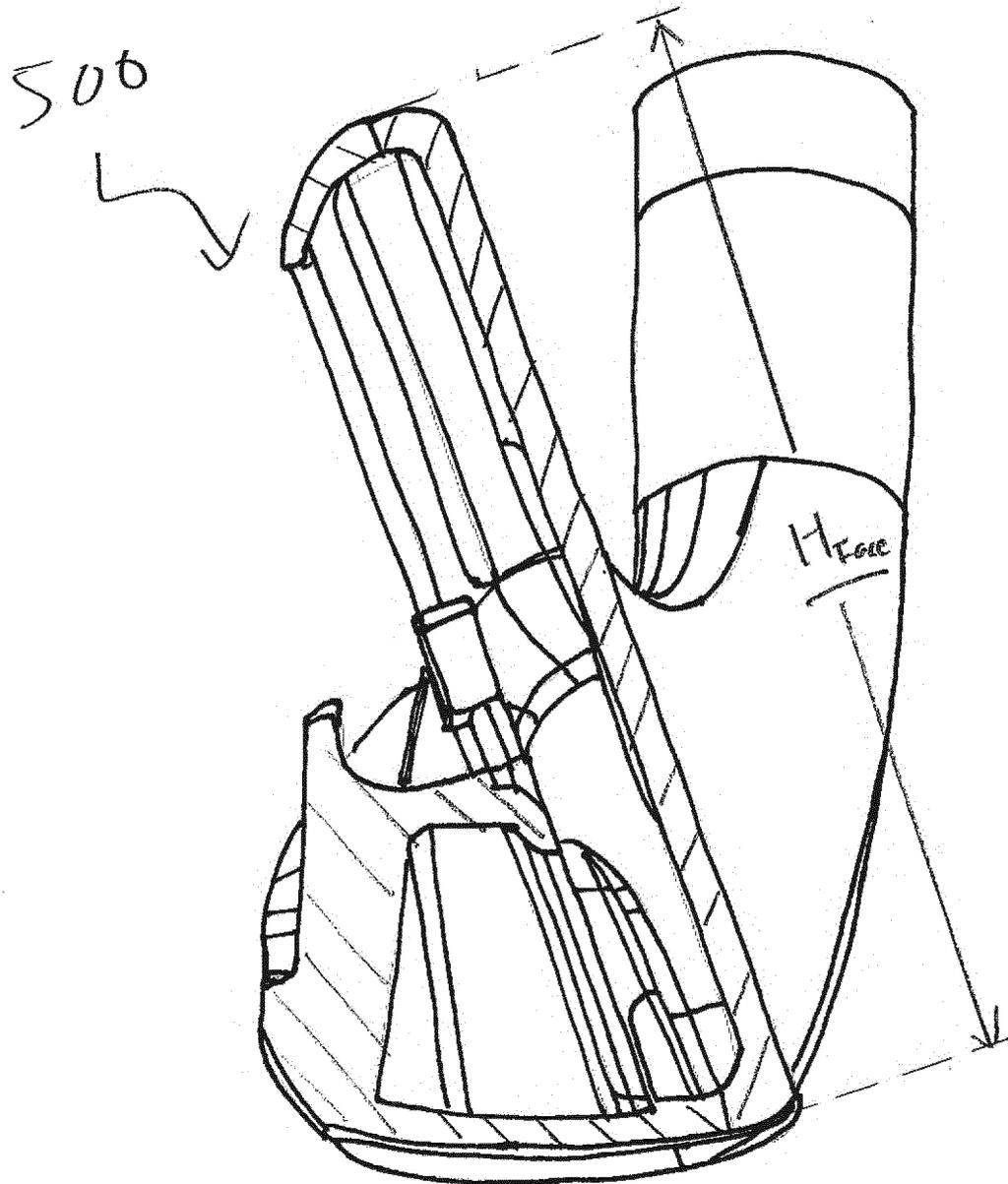


FIG. 5

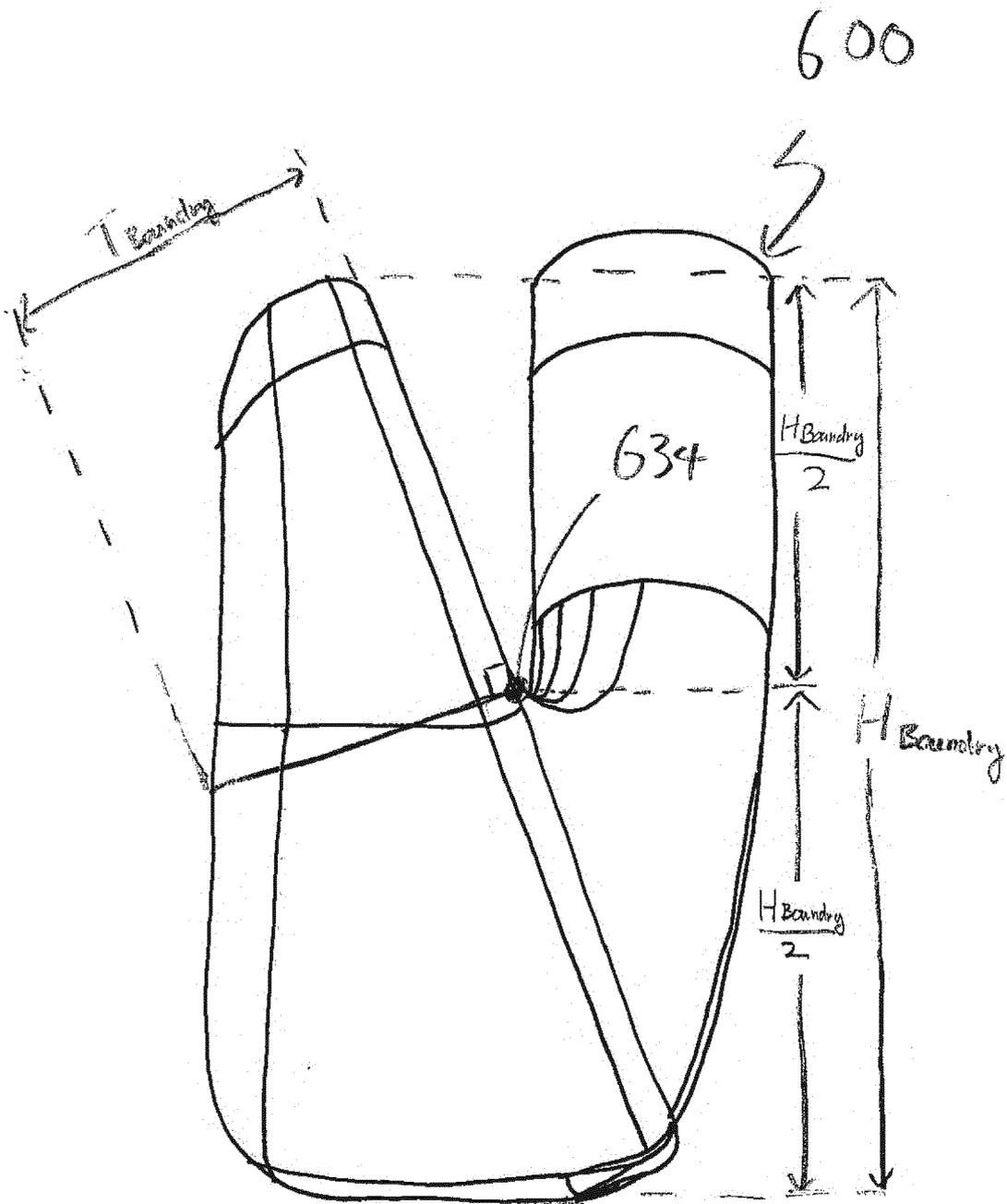


FIG. 6

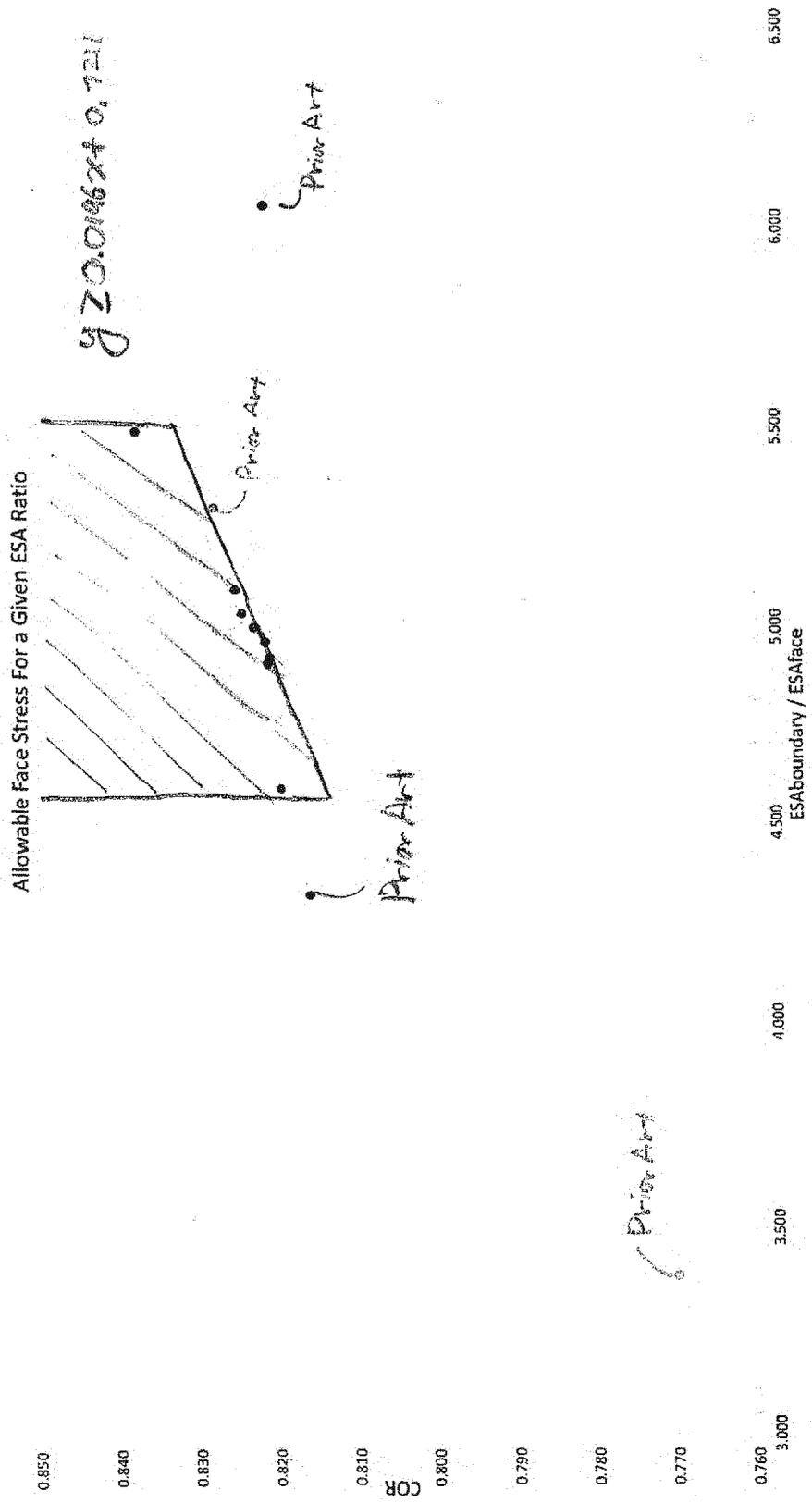


FIG. 7



EUROPEAN SEARCH REPORT

Application Number

EP 21 19 1314

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DOCUMENTS CONSIDERED TO BE RELEVANT

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	TW I 569 857 B (KARSTEN MFG CORP [US]) 11 February 2017 (2017-02-11) * paragraph [0001] - paragraph [0135]; figures 1-14 *	1-15	INV. A63B53/04
A	US 10 155 143 B2 (TAYLOR MADE GOLF CO [US]) 18 December 2018 (2018-12-18) * column 2, line 48 - column 11, line 50; figures 1-8 *	1-15	
A	US 10 625 127 B2 (ACUSHNET CO [US]) 21 April 2020 (2020-04-21) * column 6, line 22 - column 26, line 32; figures 1-17 *	1-15	
			TECHNICAL FIELDS SEARCHED (IPC)
			A63B

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The present search report has been drawn up for all claims

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Place of search <b>Munich</b>	Date of completion of the search <b>6 December 2021</b>	Examiner <b>Jekabsons, Armands</b>
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06-12-2021

Patent document cited in search report	Publication date	Patent family member(s)	Publication date	
<b>TW I569857</b>	<b>B</b>	<b>11-02-2017</b>	<b>AU 2015259460 A1</b>	<b>01-12-2016</b>
			<b>AU 2020204045 A1</b>	<b>09-07-2020</b>
			<b>CN 106659925 A</b>	<b>10-05-2017</b>
			<b>GB 2540504 A</b>	<b>18-01-2017</b>
			<b>GB 2586928 A</b>	<b>10-03-2021</b>
			<b>JP 2017515582 A</b>	<b>15-06-2017</b>
			<b>JP 2020189107 A</b>	<b>26-11-2020</b>
			<b>KR 20170008275 A</b>	<b>23-01-2017</b>
			<b>TW 201545789 A</b>	<b>16-12-2015</b>
			<b>US 2015328506 A1</b>	<b>19-11-2015</b>
<b>US 10155143</b>	<b>B2</b>	<b>18-12-2018</b>	<b>US 8535177 B1</b>	<b>17-09-2013</b>
			<b>US 2015065267 A1</b>	<b>05-03-2015</b>
			<b>US 2018085643 A1</b>	<b>29-03-2018</b>
			<b>US 2019070467 A1</b>	<b>07-03-2019</b>
<b>US 10625127</b>	<b>B2</b>	<b>21-04-2020</b>	<b>NONE</b>	

**REFERENCES CITED IN THE DESCRIPTION**

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**Patent documents cited in the description**

- US 06531020 [0001]
- US 4826172 A, Antonious [0004]
- US 5362047 A, Shaw [0005]
- US 5971868 A, Kosmatka [0006]
- US 6200228 B, Takeda [0007]
- US 7169057 B, Wood [0008]