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(71) Applicant: **KARSTEN MANUFACTURING CORPORATION** [US/US]; 2201 West Desert Cove, Phoenix, Arizona 85029 (US).

(72) Inventors: **SIMONE, Matthew W.**; 2201 West Desert Cove, Phoenix, Arizona 85029 (US). **GREER, Evan R.**; 2201 West Desert Cove, Phoenix, Arizona 85029 (US). **STOKKE, Ryan M.**; 2201 West Desert Cove, Phoenix, Arizona 85029 (US).

(74) Agent: **JENNY, Paul A.**; 2201 West Desert Cove, Phoenix, Arizona 85029 (US).

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[Continued on next page]

(54) Title: METHOD OF FORMING GOLF CLUB HEAD ASSEMBLY

(57) Abstract: A method of forming a golf club head assembly includes aligning a faceplate with a recess of a club head; welding the faceplate to the club head; then, after welding the faceplate, heating the club head and the faceplate to at least a solvus temperature of the faceplate for a predetermined amount of time; and then, after heating the club head and the faceplate, allowing the club head and the faceplate to air cool.

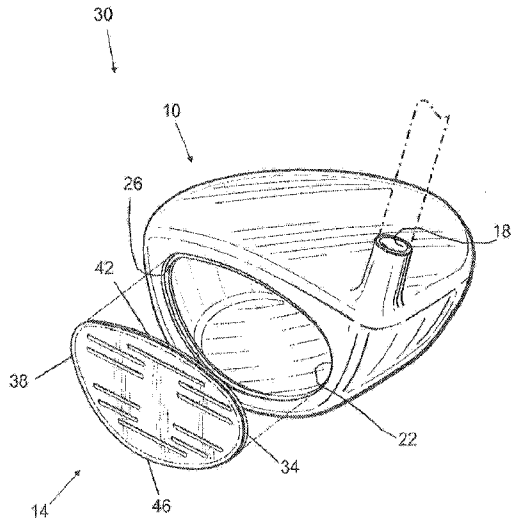

FIG. 2

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METHOD OF FORMING GOLF CLUB HEAD ASSEMBLY

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This is a continuation-in-part of U.S. Patent Application No. 14/624,488, filed on February 17, 2015, the entire contents of which are fully incorporated herein by reference.

BACKGROUND

[0002] The present invention relates to golf clubs and particularly to a method of forming a golf club head assembly.

[0003] Conventional golf club head assemblies include a faceplate welded to a club head. The faceplate has a slightly rounded shape in order to provide a straighter and/or longer flight path for a golf ball, even when the ball is struck off-center with respect to the faceplate. The faceplate has a bulge dimension, or curvature from a toe end to a heel end, and a roll dimension, or curvature from the crown edge to the sole edge.

[0004] Aspects of the invention will become apparent by consideration of the detailed description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] FIG. 1 is a perspective view of a club head and a face plate.

[0006] FIG. 2 is a perspective view of the club head with the face plate removed.

[0007] FIG. 3 is a top view of a club head assembly.

[0008] FIG. 4 is a side section view of the club head assembly of FIG. 3 along section 4--4.

[0009] FIG. 5 is a side view of the club head assembly of FIG. 3.

[0010] FIG. 6 is a schematic view of a process for forming a golf club head assembly.

[0011] FIG. 7 is a chart showing experimental bulge and roll measurements for faceplates that are subjected to various heat-treatment processes.

[0012] FIG. 8 is a chart showing experimental roll measurements for faceplates having various geometries.

[0013] FIG. 9 is a chart showing experimental bulge and roll measurements for faceplates that are subjected to various heat-treatment processes.

[0014] FIG. 10 is a chart showing durability measurements for faceplates having various material compositions.

[0015] FIG. 11A is a microstructure of non-annealed T9S. FIG. 11B is a microstructure of annealed T-9S. FIG. 11C is a stress/strain curve showing unstable yielding of the non-annealed T-9S alloy. FIG. 11D is a stress/strain curve showing a more stable yielding of the annealed T-9S alloy.

[0016] FIG. 12 is a Ti-Al phase diagram.

[0017] FIG. 13 is a chart showing experimental bulge and roll measurements for faceplates made of Ti 6-4 alloys with and without heat treat and T-9S alloys with heat treat.

[0018] FIG. 14 is a phase diagram marked with the position of T-9S and Ti 6-4 alloys.

[0019] FIG. 15 is a chart showing percentage deflection of faceplates made of Ti 6-4 alloy with no heat treat and various T9S alloys having gone through differing heat treats after these faceplates have been hit 100 and 1000 times.

[0020] Before any embodiments of the invention are explained in detail, it is to be understood that the invention is not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the following drawings. The invention is capable of other embodiments and of being practiced or of being carried out in various ways. Also, it is to be understood that the phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting. The use of "including," "comprising," and "having" and variations thereof herein is meant to encompass the items listed thereafter and equivalents thereof as well as additional items. All weight percent (wt%) numbers described below are a total weight percent.

DETAILED DESCRIPTION

[0021] FIG. 1-3 shows a golf club head 10 and a faceplate 14. In one embodiment, the golf club head 10 is formed from a cast material and the faceplate 14 is formed from a rolled material. Further, in the illustrated embodiment, the golf club head 10 is for a metal wood driver; in other embodiments, the golf club head 10 is for a fairway wood; in other embodiments, the golf club head 10 is for hybrid clubs; in other embodiments, the golf club head 10 is for an iron club. The club head 10 may also include a hosel and a hosel transition (shown as 18). For example, the hosel may be located at or proximate to the heel end 34. The hosel may extend from the club head 10 via the hosel transition 18. To form a golf club, the hosel may receive a first end of a shaft 20. The shaft 20 may be secured to the golf club head 10 by an adhesive bonding process (e.g., epoxy) and/or other suitable bonding processes (e.g., mechanical bonding, soldering, welding, and/or brazing). Further, a grip (not shown) may be secured to a second end of the shaft 20 to complete the golf club.

[0022] As shown in FIG. 2, the club head 10 further includes a recess or opening 22 for receiving the faceplate 14. In the illustrated embodiment, the opening 22 includes a lip 26 extending around the perimeter of the opening 22. The faceplate 14 is aligned with the opening and abuts the lip 26. The faceplate 14 is secured to the club head 10 by welding, forming a club head assembly 30. In one embodiment, the welding is a pulse plasma welding process.

[0023] The faceplate 14 includes a heel end 34 and a toe end 38 opposite the heel end 34. The heel end 34 is positioned proximate the hosel portion (hosel and hosel transition 18) where the shaft 20 (FIG. 1) is coupled to the club head assembly 30. The faceplate 14 further includes a crown edge 42 and a sole edge 46 opposite the crown edge 42. The crown edge 42 is positioned adjacent an upper edge of the club head 10, while the sole edge 46 is positioned adjacent the lower edge of the club head 10. As shown in FIG. 3, the faceplate 14 has a bulge curvature in a direction extending between the heel end 34 and the toe end 38. As shown in FIGS. 4 and 5, the faceplate 14 also has a roll curvature in a direction extending between the crown edge 42 and the sole edge 46. In one embodiment, the faceplate may have a minimum wall thickness of 1.5 millimeters, 1.4 millimeters, 1.3 millimeters, 1.2 millimeters, 1.1 millimeters, 1.0 millimeters, 0.9 millimeters, 0.8 millimeters, 0.7 millimeters, 0.6 millimeters, 0.5 millimeters and 0.4 millimeters. In one embodiment, the faceplate may have a minimum wall thickness of 0.7 millimeters.

[0024] The faceplate 14 is formed from a titanium alloy. In one embodiment, the faceplate 14 is an α-β titanium (α-β Ti) alloy. The α-β Ti alloy may contain neutral alloying elements such as tin and α stabilizers such as aluminum and oxygen. The α-β Ti alloy may contain β-stabilizers such as molybdenum, silicon and vanadium. All numbers described below regarding weight percent are a total weight percent (wt%). The total weight percent of α-stabilizer aluminum in α-β Ti alloy may be between 2wt% to 10wt%, 3wt% to 9wt%, 4wt% to 8wt%, 5wt% to 7wt%, 2wt% to 20 wt%, 3wt% to 19wt%, 4wt% to 18wt%, 5wt% to 17wt%, 6wt% to 16wt%, 7wt% to 15wt%, 8wt% to 14wt%, 9wt% to 13wt%, 10wt% to 12wt%, 7wt% to 9wt%, 7wt% to 10wt%, 7wt% to 11wt%, 7wt% to 12wt%, 7wt% to 13wt%, 7wt% to 14wt%, 7wt% to 15wt%, 7wt% to 16wt%, 7wt% to 17wt%, 7wt% to 18wt%, 7wt% to 19wt%, 7wt% to 20wt%, 8wt% to 10wt%, 8wt% to 11wt%, 8wt% to 12wt%, 8wt% to 13wt%, 8wt% to 14wt%, 8wt% to 15wt%, 8wt% to 16wt%, 8wt% to 17wt%, 8wt% to 18wt%, 8wt% to 19wt%, 8wt% to 20wt%, 9wt% to 11wt%, 9wt% to 12wt%, 9wt% to 13wt%, 9wt% to 14wt%, 9wt% to 15wt%, 9wt% to 16wt%, 9wt% to 17wt%, 9wt% to 18wt%, 9wt% to 19wt%, 9wt% to 20wt%, 10wt% to 13wt%, 10wt% to 14wt%, 10wt% to 15wt%, 10wt% to 16wt%, 10wt% to 17wt%, 10wt% to 18wt%, 10wt% to 19wt%, 10wt% to 20wt%, 11wt% to 13wt%, 11wt% to 14wt%, 11wt% to 15wt%, 11wt% to 16wt%, 11wt% to 17wt%, 11wt% to 18wt%, 11wt% to 19wt%, 11wt% to 20wt%, 12wt% to 14wt%, 12wt% to 15wt%, 12wt% to 16wt%, 12wt% to 17wt%, 12wt% to 18wt%, 12wt% to 19wt%, 12wt% to 20wt%, 13wt% to 15wt%, 13wt% to 16wt%, 13wt% to 17wt%, 13wt% to 18wt%, 13wt% to 19wt%, 13wt% to 20wt%, 14wt% to 16wt%, 14wt% to 17wt%, 14wt% to 18wt%, 14wt% to 19wt%, 14wt% to 20wt%, 15wt% to 17wt%, 15wt% to 18wt%, 15wt% to 19wt%, 15wt% to 20wt%, 16wt% to 18wt%, 16wt% to 19wt%, 16wt% to 20wt%, 17wt% to 19wt%, 17wt% to 20wt%, or 18wt% to 20wt%. In certain embodiments, the total weight percent of α-stabilizer aluminum in α-β Ti alloy may be between 7wt% to 13wt%, 8wt% to 13wt%, 9wt% to 13wt%, 10wt% to 13wt%, 11wt% to 13wt%, or 12wt% to 13wt%. The total weight percent of α-stabilizer oxygen in α-β Ti alloy may be between 0.05wt% to 0.35wt%, or 0.10wt% to 0.20wt%. The total weight percent of β-stabilizer molybdenum in α-β Ti alloy may be between 0.2wt% to 1.0wt%, or 0.6wt% to 0.8wt%, or trace amounts. The total weight percent of β-stabilizer vanadium in α-β Ti alloy may be between 1.5wt% to 7wt%, or 3.5wt% to 4.5wt%. The total weight percent of β-stabilizer silicon in α-β Ti alloy may be between 0.01 to 0.10wt%, or 0.03wt% to 0.07wt%. The α-β Ti alloy may be Ti-6Al-4V (or

Ti 6-4), Ti-9S (or T-9S), Ti-662, Ti-8-1-1, Ti-65K, Ti-6246, or IMI 550. The combination of α, β stabilizers allows the α-β Ti alloys to be heat treated.

[0025] In one embodiment, after welding the faceplate 14 to the club head 10, the club head 10 and faceplate 14 may be heated to a temperature at, just above, or greater than the solvus temperature of the faceplate for a predetermined amount of time. In another embodiment, after welding the faceplate 14 to the club head 10, the club head assembly 30 may be heat treated at a temperature at, just above or greater than the α-β Ti solvus temperature for a predetermined amount of time. In another embodiment, after welding the faceplate 14 to the club head 10, the club head assembly 30 may be heat treated at a temperature at, just above or greater than the α-β Ti solvus temperature for a predetermined amount of time. Also, during this step, an inert gas may be pumped into the heating chamber housing the club head assembly 30 to remove all oxygen over a predetermined amount of time discussed below. Upon cooling of the club head assembly 30 as discussed below, additional inert gas may be pumped back into the chamber where the club head assembly 30 is allowed to cool to room temperature.

[0026] As discussed above, after heating the club head assembly 30 (or the club head 10 and the welded faceplate 14), the club head assembly 30 is allowed to cool to room temperature. In another embodiment, after the heat treatment, the club head assembly 30 may be allowed to air cool to slowly reduce the club head assembly's temperature. The cooling of the club head assembly 30 may be done in an inert gas environment or non-contained environment (open air). In another embodiment, the club head assembly 30 may be allowed to cool in inert gas to slowly reduce the club head assembly's temperature and reduce chance for oxidation. The inert gas may be selected from the group consisting of nitrogen (N), argon (Ar), helium (He), neon (Ne), krypton (Kr), and xenon (Xe) or a compound gas thereof. After heating to, just above, or greater than the α-β Ti solvus temperature, inert gas may be pumped back into a chamber under vacuum housing the club assembly 30, which ensures no oxygen is present to prevent oxidation to the titanium faceplate 14 and club head surfaces 10.

[0027] As understood by a person of ordinary skill, the solvus temperature for an alloy is the temperature barrier at which smaller constituent molecules dissolve within the general matrix of the material and become more mobile. The solvus temperatures of most α-β Ti alloys are verified and readily available in academic literature or information published by

material suppliers. If published data is unavailable, the temperature values can be estimated and experimentally confirmed, since it is dependent on the material's chemistry. The solvus temperature for α-β Ti can be above 400 °C and below 600 °C, above 400 °C and below 1180 °C. In certain embodiments, the solvus temperature for α-β Ti alloy can be between 500 °C and 1030 °C, 680 °C and 1030 °C, 760 °C and 1030 °C, 870 °C and 1030 °C, 895 °C and 1030 °C, or 960 °C and 1030 °C.

[0028] In one embodiment, the α-β Ti may be Ti 6-4 containing 6wt% aluminum (Al), and 4wt% vanadium (V), with the remaining alloy composition being titanium and possibly some trace elements. In some embodiments, Ti 6-4 contains between 5.5wt%-6.75wt% Al, between 3.5wt%-4.5wt% V, a maximum of 0.08wt% carbon (C), a maximum of 0.03wt% silicon (Si), a maximum of 0.3wt% iron (Fe), a maximum of 0.2wt% oxygen (O), a maximum of 0.015wt% tin (Sn), and trace amounts of molybedenum (Mo), with the remaining alloy composition being titanium. In some embodiments, Ti 6-4 contains between 5.5wt%-6.75wt% Al, between 3.5wt%-4.5wt% V, 0.08wt% or less carbon (C), 0.03wt% or less silicon (Si), 0.3wt% or less iron (Fe), 0.2wt% or less oxygen (O), 0.015wt% or less tin (Sn), and trace amounts of molybedenum (Mo), with the remaining alloy composition being titanium. Ti 6-4 is a grade 5 titanium. The solvus temperature for Ti 6-4 is between 540 °C and 560 °C. In some embodiments, Ti 6-4 has a density of 0.1597 lb/in^3 (4.37 g/cc). Ti-6-4 may also be designated as T-65K.

[0029] In other embodiments, the faceplate 14 of the golf club head 10 may be another α-β Ti alloy, such as Ti-9S (or T-9S), which contains 8wt% Al, 1wt% V, and 0.2wt% Si, with the remaining alloy composition being titanium and possibly some trace elements. In some embodiments, Ti-9S (or T-9S) contains 6.5wt%-8.5wt% Al, between 1wt%-2wt% V, a maximum of 0.08wt% C, a maximum of 0.2wt% Si, a maximum of 0.3wt% Fe, a maximum of 0.2wt% O, a maximum of 0.05wt% N, trace amounts of Mo, and trace amounts of Sn, with the remaining alloy composition being titanium. In some embodiments, Ti-9S (or T-9S) contains 6.5wt%-8.5wt% Al, between 1wt%-2wt% V, less than 0.1wt% C, a maximum of 0.2wt% Si, a maximum of 0.4wt% Fe, a maximum of 0.15wt% O, less than 0.05wt% N, trace amounts of Mo, and trace amounts of Sn, with the remaining alloy composition being titanium. In some embodiments, Ti-9S (or T-9S) contains 6.5wt%-8.5wt% Al, between 1wt%-2wt% V, 0.1wt% or less C, 0.2wt% or less Si, 0.4wt% or less Fe, 0.15wt% or less O, less than 0.05wt% N, trace amounts of Mo, and trace amounts of Sn, with the remaining alloy

composition being titanium. The solvus temperature for Ti-9S (or T-9S) is between 560 °C and 590 °C. In some embodiments, the Ti-9S (or T-9s) will have higher porosity and a lower yield than Ti 8-1-1. Ti-9S (or T-9S) has a density of about 0.156 lb/in^3 to 0.157 lb/in^3 (4.32-4.35 g/cc). Ti-9S (or T-9S) has a density of 0.156 lb/in^3 (4.32g/cc).

[0030] In other embodiments, the material may be another α-β Ti alloy, such as Ti-6-6-2, Ti-6246, or IMI 550. Titanium 662 may contain 6wt% Al, 6wt% V, and 2wt% Sn, with the remaining alloy composition being titanium and possibly some trace elements. Ti-6-6-2 has a density of 0.164 lb/in3 (4.54 g/cc). The solvus temperature for Ti 662 is between 540 °C and 560 °C. Titanium 6246 may contain 6wt% Al, 2wt% Sn, 4wt% zirconium (Zr), and 6wt% Mo, with the remaining alloy composition being titanium and possibly some trace elements. The solvus temperature for Ti 6246 is between 570 °C and 590 °C. Ti-6246 has a density of 0.168 lb/in3 (4.65 g/cc). IMI 550 may contain 6wt% Al, 2wt% Sn, 4wt% Mo, and 0.5wt% Si, with the remaining alloy composition being titanium and possibly some trace elements. The solvus temperature for IMI 550 is between 490 °C and 510 °C. IMI 550 has a density of .157 lb/in^3 (4.60 g/cc).

[0031] In other embodiments, the material may be another α-β Ti alloy, such as Ti-8-1-1, which may contain 8wt% Al, 1.0wt% Mo, and 1wt% V, with the remaining alloy composition being titanium and possibly some trace elements. In some embodiments, Ti-8-1-1 may contain 7.5wt%-8.5wt% Al, 0.75wt%-1.25wt% Mo., 0.75wt%-1.25wt% V, a maximum of 0.08wt% C, a maximum of 0.3wt% Fe, a maximum of 0.12wt% O, a maximum of 0.05wt% N, a maximum of 0.015wt% H, a maximum of 0.015wt% Sn, and trace amounts of Si, with the remaining alloy composition being titanium. The solvus temperature for Ti-8-1-1 is between 560 °C and 590 °C. In some embodiments, Ti-8-1-1 has a density of 0.1580 lb/in^3 (4.37 g/cc).

[0032] In other embodiments, the material may be another α-β Ti alloy which may contain 7wt%-8wt% Al with the remaining alloy composition being titanium and other α- and β-stabilizers. The solvus temperature for this α-β Ti is between 500 °C and 720 °C.

[0033] In other embodiments, the material may be another α-β Ti alloy which may contain 8wt%-9wt% Al with the remaining alloy composition being titanium and other α- and β-stabilizers. The solvus temperature for this α-β Ti is between 680 °C and 810 °C.

[0034] In other embodiments, the material may be another α-β Ti alloy which may contain 9wt%-10wt% Al with the remaining alloy composition being titanium and other α- and β-stabilizers. The solvus temperature for this α-β Ti is between 760 °C and 895 °C.

[0035] In other embodiments, the material may be another α-β Ti alloy which may contain 10wt%-11wt% Al with the remaining alloy composition being titanium and other α- and β-stabilizers. The solvus temperature for this α-β Ti is between 870 °C and 910 °C.

[0036] In other embodiments, the material may be another α-β Ti alloy which may contain 11wt%-12wt% Al with the remaining alloy composition being titanium and other α- and β-stabilizers. The solvus temperature for this α-β Ti is between 890 °C and 980 °C.

[0037] In other embodiments, the material may be another α-β Ti alloy which may contain 12wt%-13wt% Al with the remaining alloy composition being titanium and other α- and β-stabilizers. The solvus temperature for this α-β Ti is between 960 °C and 1030 °C.

[0038] In other embodiments, the material may be another α-β Ti alloy which may contain 13wt%-14wt% Al with the remaining alloy composition being titanium and other α- and β-stabilizers. The solvus temperature for this α-β Ti is between 980 °C and 1070 °C.

[0039] In other embodiments, the material may be another α-β Ti alloy which may contain 14wt%-15wt% Al with the remaining alloy composition being titanium and other α- and β-stabilizers. The solvus temperature for this α-β Ti is between 1030 °C and 1100 °C.

[0040] In other embodiments, the material may be another α-β Ti alloy which may contain 16wt%-17wt% Al with the remaining alloy composition being titanium and other α- and β-stabilizers. The solvus temperature for this α-β Ti is between 1100 °C and 1140 °C.

[0041] In other embodiments, the material may be another α-β Ti alloy which may contain 17wt%-18wt% Al with the remaining alloy composition being titanium and other α- and β-stabilizers. The solvus temperature for this α-β Ti is between 1140 °C and 1150 °C.

[0042] In other embodiments, the material may be another α-β Ti alloy which may contain 18wt%-19wt% Al with the remaining alloy composition being titanium and other α- and β-stabilizers. The solvus temperature for this α-β Ti is between 1150 °C and 1180 °C.

[0043] In other embodiments, the material may be another α-β Ti alloy which may contain 19wt%-20wt% Al with the remaining alloy composition being titanium and other α- and β-stabilizers. The solvus temperature for this α-β Ti is between 1170 °C and 1180 °C.

[0044] In other embodiments, the material may be another α-β Ti alloy which may contain 7wt%-13wt% Al with the remaining alloy composition being titanium and other α- and β-stabilizers. The solvus temperature for this α-β Ti is between 500 °C and 1030 °C.

[0045] In other embodiments, the material may be another α-β Ti alloy which may contain 8wt%-13wt% Al with the remaining alloy composition being titanium and other α- and β-stabilizers. The solvus temperature for this α-β Ti is between 680 °C and 1030 °C.

[0046] In other embodiments, the material may be another α-β Ti alloy which may contain 9wt%-13wt% Al with the remaining alloy composition being titanium and other α- and β-stabilizers. The solvus temperature for this α-β Ti is between 760 °C and 1030 °C.

[0047] In other embodiments, the material may be another α-β Ti alloy which may contain 10wt%-13wt% Al with the remaining alloy composition being titanium and other α- and β-stabilizers. The solvus temperature for this α-β Ti is between 870 °C and 1030 °C.

[0048] In other embodiments, the material may be another α-β Ti alloy which may contain 11wt%-13wt% Al with the remaining alloy composition being titanium and other α- and β-stabilizers. The solvus temperature for this α-β Ti is between 890 °C and 1030 °C.

[0049] In other embodiments, the material may be another α-β Ti alloy which may contain 12wt%-13wt% Al with the remaining alloy composition being titanium and other α- and β-stabilizers. The solvus temperature for this α-β Ti is between 960 °C and 1030 °C.

[0050] FIG. 6 shows the process for forming for the club head assembly 30. In the first step 62, the faceplate 14 is aligned with respect to the club head 10. The second step 66 involves welding the faceplate 14 to the club head 10. In the third step 70, the club head 10 and the faceplate 14 are heated to a temperature at or above the solvus temperature of the faceplate 14 material. Finally, in the fourth step 74 the club head 10 and the faceplate 14 are air cooled.

[0051] In one embodiment, the club head assembly 30 is heat treated at a temperature at or above the solvus temperature of the α-β Ti alloy for between 1 hour and 6 hours in the

third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature at or above the solvus temperature of the α-β Ti alloy for between 1 hour and 2 hours in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature at or above the solvus temperature of the α-β Ti alloy for between 1 hour and 4 hours in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature at or above the solvus temperature of the α-β Ti alloy for between 4 hours and 6 hours in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature at or above the solvus temperature of the α-β Ti alloy for between 1.5 hours and 5.5 hours in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature at or above the solvus temperature of the α-β Ti alloy for between 2 hours and 5 hours in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature at or above the solvus temperature of the α-β Ti alloy for between 2.5 hours and 4.5 hours in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature at or above the solvus temperature of the α-β Ti alloy for between 3 hours and 4 hours in the third step 70.

[0052] In one embodiment, the club head assembly 30 is heat treated at a temperature at or above the solvus temperature of the α-β Ti alloy for at least 1 hour in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature at or above the solvus temperature of the α-β Ti alloy for at least 1.5 hours in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature at or above the solvus temperature of the α-β Ti alloy for at least 2 hours in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature at or above the solvus temperature of the α-β Ti alloy for at least 2.5 hours in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature at or above the solvus temperature of the α-β Ti alloy for at least 3 hours in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature at or above the solvus temperature of the α-β Ti alloy for at least 3.5 hours in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature at or above the solvus temperature of the α-β Ti alloy for at least 4 hours in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature at or above the solvus temperature of the α-β Ti alloy for at least 4.5 hours in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature at or above the solvus temperature of the α-β Ti alloy for at least 5 hours in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature

at or above the solvus temperature of the α-β Ti alloy for at least 5.5 hours in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature at or above the solvus temperature of the α-β Ti alloy for at least 6 hours in the third step 70.

[0053] In one embodiment, the club head assembly 30 is heat treated between 400 °C and 630 °C, between 400 °C and 1200 °C, or between 500 °C and 1030 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated between 425 °C and 550 °C, between 425 °C and 1200 °C, or between 525 °C and 1030 °C. In one embodiment, the club head assembly 30 is heat treated between 450 °C and 525 °C, between 450 °C and 1095 °C, or between 550 °C and 925 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated between 550 °C and 625 °C, between 550 °C and 1195 °C, or between 650 °C and 925 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated between 520 °C and 1200 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated between 620 °C and 1150 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated between 720 °C and 1000 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated between 820 °C and 950 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated between 720 °C and 900 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated between 820 °C and 850 °C in the third step 70.In one embodiment, the club head assembly 30 is heat treated at 400 °C, 410 °C, 420 °C, 430 °C, 440 °C, 450 °C, 460 °C, 470 °C, 480 °C, 490 °C, 500 °C, 510 °C, 520 °C, 530 °C, 540 °C, 550 °C, 560 °C, 570 °C, 580 °C, 590 °C, 600 °C, 610 °C, 620 °C, 630 °C, 640 °C, 650 °C, 660 °C, 670 °C, 680 °C, 690 °C, 700 °C, 710 °C, 720 °C, 730 °C, 740 °C, 750 °C, 760 °C, 770 °C, 780 °C, 790 °C, 800 °C, 810 °C, 820 °C, 830 °C, 840 °C, 850 °C, 860 °C, 870 °C, 880 °C, 890 °C, 900 °C, 910 °C, 920 °C, 930 °C, 940 °C, 950 °C, 960 °C, 970 °C, 980 °C, 990 °C, 1000 °C, 1010 °C, 1020 °C, 1030 °C, 1040 °C, 1050 °C, 1060 °C, 1070 °C, 1080 °C, 1090 °C, 1100 °C, 1110 °C, 1120 °C, 1130 °C, 1140 °C, 1150 °C, 1160 °C, 1170 °C, 1180 °C, 1190 °C, or 1200 °C in the third step 70 for 30 minutes, 60 minutes, 90 minutes, 120 minutes, 150 minutes, 180 minutes, 210 minutes, 240 minutes, 270 minutes, 300 minutes, 330 minutes or 360 minutes.

[0054] In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 400 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 420 °C in the third step 70. In one embodiment, the club

head assembly 30 is heat treated at a temperature of at least 440 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 460 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 475 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 480 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 500 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 520 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 540 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 560 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 575 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 580 °C. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 600 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 620 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 625 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 630 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 640 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 660 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 675 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 680 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 700 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 720 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 740 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 760 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 775 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 780°C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 800°C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 820 °C in the third step 70. In one

embodiment, the club head assembly 30 is heat treated at a temperature of at least 840 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 860 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 875 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 880 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 900 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 920 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 940 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 960 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 975°C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 980°C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 1000°C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 1020°C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 1040°C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 1060°C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 1075°C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 1080°C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 1100°C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 1120 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 1140 °C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 1160°C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 1175°C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 1180°C in the third step 70. In one embodiment, the club head assembly 30 is heat treated at a temperature of at least 1200°C in the third step 70.

[0055] In one embodiment, the club head assembly 30 is heat treated between 475 °C and 500 °C for between 4 hours and 6 hours in the third step 70. In another embodiment, the club

head is heat treated between 575 °C and 625 °C for between 1 hour and 2 hours in the third step 70. In another embodiment, the club head is heat treated at about 550 °C for between 1 hour and 4 hours. In other embodiments, the face plate 14 may be formed from a different alloy in the third step 70. In other embodiments, the heat treatment process may be implemented at other temperatures for a different amount of time. In addition, the heat treatment may be applied to a variety of materials and a variety of weld-types.

[0056] Unlike conventional club head metal aging processes that occur at low temperature, heat-treating the club head assembly 30 above the solvus temperature after welding the faceplate 14 relieves stresses in the faceplate 14 and between the weld and the metal matrix of the club head 10. The post-weld stress relief disperses stresses associated with the weld-metal heat affected zone (HAZ), or the area around the weld in which the material properties have been altered due to the welding process. Because of the stark contrast in mechanical properties between the HAZ and the rest of the metal matrix, the HAZ is much more likely to experience a crack and fail. Previous post-weld treatments were performed below the solvus temperature for a short duration of time. These processes simply aged the metals, but did not address the increased stresses transferred to the weld area. Furthermore, the faceplate was not sufficiently strong and would flatten or lose its curvature relatively quickly. In contrast, the heat treatment above the solvus temperature disperses stresses in the weld metal HAZ. The heat-treatment improves the durability of the HAZ by relieving the stresses. In addition, heat-treating the club head assembly 30 above the solvus temperature reduces the possibility of generating titanium-aluminum (Ti_3Al) crystals along the weld.

[0057] The grains of the faceplate alloy may be aligned in a crown to sole orientation prior to heat treating. The crown to sole orientation of the alloy grains permits stretching in the same direction. In some embodiments, the grains of the faceplate α-β titanium (α-β Ti) alloy may be aligned in a crown to sole orientation prior to heat treating. The crown to sole orientation of the α-β Ti alloy grains permits stretching in the same direction. In some embodiments, the grains of the faceplate disclosed α-β Ti alloys (e.g., Ti-6Al-4V (or Ti 6-4), Ti-9S (or T-9S), Ti-662, Ti-8-1-1, Ti-65K, Ti-6246, and IMI 550alloy) may be aligned in a crown to sole orientation prior to heat treating. The crown to sole orientation of the disclosed α-β Ti alloys(e.g., Ti-6Al-4V (or Ti 6-4), Ti-9S (or T-9S), Ti-662, Ti-8-1-1, Ti-65K, Ti-6246, or IMI 550 alloy) grains permits stretching in the same direction.

[0058] The heat treatment also improves the toughness or durability of the faceplate 14. The improved toughness permits the faceplate 14 to be made thinner without sacrificing durability, thereby reducing club head weight. The reduced weight of faceplate 14 shifts the center of gravity of the club head assembly 30, and allows additional weight to be added to another component of the club to further adjust the center of gravity. Increasing the durability of the faceplate 14 permits the faceplate 14 to endure a significantly higher number of hits against a golf ball and maintain the faceplate's slightly bowed or rounded shape over the life of the club while sustaining hundreds or thousands of golf ball strikes. Therefore, the club is more forgiving when a ball is struck off-center because the rounded shape of the faceplate 14 provides a "gear effect" between the ball and faceplate 14.

[0059] As shown in FIG. 7, an experiment was performed to compare the effect of various heat treatment temperatures on the faceplate 14 over the course of 2,000 hits or ball strikes. The faceplates 14 were formed from Ti-9S (or T-9S) alloy. One club head assembly was heated to 400 °C, which is below the solvus temperature of the Ti-9S (or T-9S) alloy. A second club head assembly was heated to 600 °C, which is above the solvus temperature of the Ti-9S (or T-9S) alloy. The measurement data provided in FIG. 7 represent the percent change in the radius of curvature of the bulge and the roll dimensions compared to the original radius curvature. As the faceplate becomes more flat, the radius of curvature increases. The club head assembly having a faceplate 14 with Ti-9S treated at 400 °C flattened significantly in both its roll and bulge dimensions within 25 hits on a golf ball. In contrast, the club head assembly having a Ti-9S faceplate treated at 600 °C maintained its curvature significantly better than the first club head assembly after 2,000 hits. The Ti-9S faceplate treated at 600 °C maintained its' curvature better after 2000 hits than the first club head assembly having a faceplate 14 of Ti-6-4 untreated maintained curvature in both roll and bulge dimensions.

[0060] For heat treatments below the solvus temperature (for example, at 400 °C), Ti_3Al particles become more mobile and can precipitate into the α-matrix. Some of the Ti_3Al particles gather at grain boundaries and age harden the material. In contrast, for heat treatments above the solvus temperature (for example, at 600 °C), Ti_3Al particles instead dissolve within the α-matrix. The brittle Ti_3Al particles can act as points of stress. Dissolving brittle Ti_3Al particles within the α-matrix thereby acts as a stress relief. This

"stress relief" process enables the club head assembly 30 to better withstand tensile and compressive forces during impact against a golf ball.

[0061] In one embodiment, the faceplate 14 that is formed from Ti-9S (or T-9S) and heat treated above the solvus temperature of Ti-9S (or T-9S) remains within 2% deflection of its original bulge and roll curvature after about 25 strikes. In one embodiment, the faceplate 14 that is formed from Ti 6-4 and heat treated above the solvus temperature of Ti 6-4 remains within 3% deflection of its original roll curvature and within 8% deflection of its original bulge curvature after about 25 strikes.

[0062] In one embodiment, the faceplate 14 that is formed from Ti-9S (or T-9S) and heat treated above the solvus temperature of Ti-9S (or T-9S) remains within 8% deflection of its original bulge and roll curvature after about 50 strikes. In one embodiment, the faceplate 14 that is formed from Ti 6-4 and heat treated above the solvus temperature of Ti 6-4 remains within 5% deflection of its original roll curvature and within 10% deflection of its original bulge curvature after about 50 strikes.

[0063] In one embodiment, the faceplate 14 that is formed from Ti-9S (or T-9S) and heat treated above the solvus temperature of Ti-9S (or T-9S) remains within 10% deflection of its original bulge and roll curvature after about 75 strikes. In one embodiment, the faceplate 14 that is formed from Ti 6-4 and heat treated above the solvus temperature of Ti 6-4 remains within 13% deflection of its original roll curvature and within 10% deflection of its original bulge curvature after about 75 strikes.

[0064] In one embodiment, the faceplate 14 that is formed from Ti-9S (or T-9S) and heat treated above the solvus temperature of Ti-9S (or T-9S) remains within 10% deflection of its original bulge and roll curvature after about 100 strikes. In one embodiment, the faceplate 14 that is formed from Ti 6-4 and heat treated above the solvus temperature of Ti 6-4 remains within 14% deflection of its original roll curvature and within 10% deflection of its original bulge curvature after about 100 strikes.

[0065] In one embodiment, the faceplate 14 that is formed from Ti-9S (or T-9S) and heat treated above the solvus temperature of Ti-9S (or T-9S) remains within 10% deflection of its original bulge and roll curvature after about 150 strikes. In one embodiment, the faceplate 14 that is formed from Ti 6-4 and heat treated above the solvus temperature of Ti 6-4 remains

within 15% deflection of its original roll curvature and within 11% deflection of its original bulge curvature after about 150 strikes.

[0066] In one embodiment, the faceplate 14 that is formed from Ti-9S (or T-9S) and heat treated above the solvus temperature of Ti-9S (or T-9S) remains within 10% deflection of its original bulge and roll curvature after about 300 strikes. In one embodiment, the faceplate 14 that is formed from Ti 6-4 and heat treated above the solvus temperature of Ti 6-4 remains within 15% deflection of its original roll and bulge curvature after about 300 strikes.

[0067] In one embodiment, the faceplate 14 that is formed from Ti-9S (or T-9S) and heat treated above the solvus temperature of Ti-9S (or T-9S) remains within 10% deflection of its original bulge and roll curvature after about 1,000 strikes. In one embodiment, the faceplate 14 that is formed from Ti 6-4 and heat treated above the solvus temperature of Ti 6-4 remains within 23% deflection of its original roll curvature and within 17% deflection of its original bulge curvature after about 1,000 strikes.

[0068] In one embodiment, the faceplate 14 that is formed from Ti-9S (or T-9S) and heat treated above the solvus temperature of Ti-9S (or T-9S) remains within 10% deflection of its original bulge and roll curvature after about 2,000 strikes. In one embodiment, the faceplate 14 that is formed from Ti 6-4 and heat treated above the solvus temperature of Ti 6-4 remains within 24% deflection of its original roll curvature and within 18% deflection of its original bulge curvature after about 2,000 strikes.

[0069] Furthermore, an experiment was performed to compare the effect of various heat treatment temperatures on the faceplate 14 over the course of 2,000 hits or ball strikes. The faceplate 14 was formed from α-β Ti alloy. One club head assembly was heated to 400 °C, which is below the solvus temperature of the α-β Ti alloy. A second club head assembly was heated to 600 °C, which is above the solvus temperature of the α-β Ti alloy. The club head assembly treated at 400 °C flattened significantly in both its roll and bulge dimensions within 25 hits on a golf ball. In contrast, the club head assembly treated at 600 °C did not begin to flatten until 225 strikes on a golf ball and maintained its curvature significantly better than the first club head assembly after 2,000 hits.

[0070] In one embodiment, the club head assembly treated at 500 °C maintained its original bulge and roll curvature after 25 hits. In one embodiment, the club head assembly treated at 500 °C maintained its original bulge and roll curvature after 50 hits. In one

embodiment, the club head assembly treated at 500 °C maintained its original bulge and roll curvature after 75 hits. In one embodiment, the club head assembly treated at 500 °C maintained its original bulge and roll curvature after 100 hits. In one embodiment, the club head assembly treated at 500 °C maintained its original bulge and roll curvature after 125 hits. In one embodiment, the club head assembly treated at 500 °C maintained its original bulge and roll curvature after 150 hits. In one embodiment, the club head assembly treated at 500 °C maintained its original bulge and roll curvature after 175 hits. In one embodiment, the club head assembly treated at 500 °C maintained its original bulge and roll curvature after 200 hits. In one embodiment, the club head assembly treated at 500 °C maintained its original bulge and roll curvature after 225 hits.

[0071] In one embodiment, the club head assembly treated at 500 °C substantially maintained its bulge and roll curvature after 250 hits. In one embodiment, the club head assembly treated at 500 °C substantially maintained its bulge and roll curvature after 275 hits. In one embodiment, the club head assembly treated at 500 °C substantially maintained its bulge and roll curvature after 300 hits. In one embodiment, the club head assembly treated at 500 °C substantially maintained its bulge and roll curvature after 500 hits. In one embodiment, the club head assembly treated at 500 °C substantially maintained its bulge and roll curvature after 1,000 hits. In one embodiment, the club head assembly treated at 500 °C substantially maintained its bulge and roll curvature after 1500 hits. In one embodiment, the club head assembly treated at 500 °C substantially maintained its bulge and roll curvature after 2,000 hits.

[0072] In one embodiment, the club head assembly treated at 600 °C maintained its original bulge and roll curvature after 25 hits. In one embodiment, the club head assembly treated at 600 °C maintained its original bulge and roll curvature after 50 hits. In one embodiment, the club head assembly treated at 600 °C maintained its original bulge and roll curvature after 75 hits. In one embodiment, the club head assembly treated at 600 °C maintained its original bulge and roll curvature after 100 hits. In one embodiment, the club head assembly treated at 600 °C maintained its original bulge and roll curvature after 125 hits. In one embodiment, the club head assembly treated at 600 °C maintained its original bulge and roll curvature after 150 hits. In one embodiment, the club head assembly treated at 600 °C maintained its original bulge and roll curvature after 175 hits. In one embodiment, the club head assembly treated at 600 °C maintained its original bulge and roll curvature after

200 hits. In one embodiment, the club head assembly treated at 600 °C maintained its original bulge and roll curvature after 225 hits.

[0073] In one embodiment, the club head assembly treated at 600 °C substantially maintained its bulge and roll curvature after 250 hits. In one embodiment, the club head assembly treated at 600 °C substantially maintained its bulge and roll curvature after 275 hits. In one embodiment, the club head assembly treated at 600 °C substantially maintained its bulge and roll curvature after 300 hits. In one embodiment, the club head assembly treated at 600 °C substantially maintained its bulge and roll curvature after 500 hits. In one embodiment, the club head assembly treated at 600 °C substantially maintained its bulge and roll curvature after 1,000 hits. In one embodiment, the club head assembly treated at 600 °C substantially maintained its bulge and roll curvature after 1500 hits. In one embodiment, the club head assembly treated at 600 °C substantially maintained its bulge and roll curvature after 2,000 hits.

[0074] In one embodiment, the club head assembly treated at 600 °C maintained its original bulge curvature and its roll curvature radius increased from 11 inches to 13 inches after 250 hits. In one embodiment, the club head assembly treated at 600 °C maintained its original bulge curvature and maintained a roll curvature radius of 13 inches after 275 hits. In one embodiment, the club head assembly treated at 600 °C increased its bulge curvature radius from 12 inches to 13 inches and maintained a roll curvature radius of 13 inches after 300 hits. In one embodiment, the club head assembly treated at 600 °C maintained its bulge curvature radius of 13 inches and maintained a roll curvature radius of 13 inches after 500 hits. In one embodiment, the club head assembly treated at 600 °C maintained its bulge curvature radius of 13 inches and increased its roll curvature radius from 13 inches to 14 inches after 1,000 hits. In one embodiment, the club head assembly treated at 600 °C maintained its bulge curvature radius of 13 inches and maintained a roll curvature radius of 14 inches after 1,500 hits. In one embodiment, the club head assembly treated at 600 °C maintained its bulge curvature radius of 13 inches and maintained a roll curvature radius of 14 inches after 2,000 hits.

[0075] In one embodiment, the club head assembly treated at 700 °C maintained its original bulge and roll curvature after 25 hits. In one embodiment, the club head assembly treated at 700 °C maintained its original bulge and roll curvature after 50 hits. In one embodiment, the club head assembly treated at 700 °C maintained its original bulge and

roll curvature after 75 hits. In one embodiment, the club head assembly treated at 700 °C maintained its original bulge and roll curvature after 100 hits. In one embodiment, the club head assembly treated at 700 °C maintained its original bulge and roll curvature after 125 hits. In one embodiment, the club head assembly treated at 700 °C maintained its original bulge and roll curvature after 150 hits. In one embodiment, the club head assembly treated at 700 °C maintained its original bulge and roll curvature after 175 hits. In one embodiment, the club head assembly treated at 700 °C maintained its original bulge and roll curvature after 200 hits. In one embodiment, the club head assembly treated at 700 °C maintained its original bulge and roll curvature after 225 hits.

[0076] In one embodiment, the club head assembly treated at 700 °C substantially maintained its bulge and roll curvature after 250 hits. In one embodiment, the club head assembly treated at 700 °C substantially maintained its bulge and roll curvature after 275 hits. In one embodiment, the club head assembly treated at 700 °C substantially maintained its bulge and roll curvature after 300 hits. In one embodiment, the club head assembly treated at 700 °C substantially maintained its bulge and roll curvature after 500 hits. In one embodiment, the club head assembly treated at 700 °C substantially maintained its bulge and roll curvature after 1,000 hits. In one embodiment, the club head assembly treated at 700 °C substantially maintained its bulge and roll curvature after 1500 hits. In one embodiment, the club head assembly treated at 700 °C substantially maintained its bulge and roll curvature after 2,000 hits.

[0077] In one embodiment, the club head assembly treated at 800 °C maintained its original bulge and roll curvature after 25 hits. In one embodiment, the club head assembly treated at 800 °C maintained its original bulge and roll curvature after 50 hits. In one embodiment, the club head assembly treated at 800 °C maintained its original bulge and roll curvature after 75 hits. In one embodiment, the club head assembly treated at 800 °C maintained its original bulge and roll curvature after 100 hits. In one embodiment, the club head assembly treated at 800 °C maintained its original bulge and roll curvature after 125 hits. In one embodiment, the club head assembly treated at 800 °C maintained its original bulge and roll curvature after 150 hits. In one embodiment, the club head assembly treated at 800 °C maintained its original bulge and roll curvature after 175 hits. In one embodiment, the club head assembly treated at 800 °C maintained

its original bulge and roll curvature after 200 hits. In one embodiment, the club head assembly treated at 800 °C maintained its original bulge and roll curvature after 225 hits.

[0078] In one embodiment, the club head assembly treated at 800 °C substantially maintained its bulge and roll curvature after 250 hits. In one embodiment, the club head assembly treated at 800 °C substantially maintained its bulge and roll curvature after 275 hits. In one embodiment, the club head assembly treated at 800 °C substantially maintained its bulge and roll curvature after 300 hits. In one embodiment, the club head assembly treated at 800 °C substantially maintained its bulge and roll curvature after 500 hits. In one embodiment, the club head assembly treated at 800 °C substantially maintained its bulge and roll curvature after 1,000 hits. In one embodiment, the club head assembly treated at 800 °C substantially maintained its bulge and roll curvature after 1500 hits. In one embodiment, the club head assembly treated at 800 °C substantially maintained its bulge and roll curvature after 2,000 hits.

[0079] In one embodiment, the club head assembly treated at 900 °C maintained its original bulge and roll curvature after 25 hits. In one embodiment, the club head assembly treated at 900 °C maintained its original bulge and roll curvature after 50 hits. In one embodiment, the club head assembly treated at 900 °C maintained its original bulge and roll curvature after 75 hits. In one embodiment, the club head assembly treated at 900 °C maintained its original bulge and roll curvature after 100 hits. In one embodiment, the club head assembly treated at 900 °C maintained its original bulge and roll curvature after 125 hits. In one embodiment, the club head assembly treated at 900 °C maintained its original bulge and roll curvature after 150 hits. In one embodiment, the club head assembly treated at 900 °C maintained its original bulge and roll curvature after 175 hits. In one embodiment, the club head assembly treated at 900 °C maintained its original bulge and roll curvature after 200 hits. In one embodiment, the club head assembly treated at 900 °C maintained its original bulge and roll curvature after 225 hits.

[0080] In one embodiment, the club head assembly treated at 900 °C substantially maintained its bulge and roll curvature after 250 hits. In one embodiment, the club head assembly treated at 900 °C substantially maintained its bulge and roll curvature after 275 hits. In one embodiment, the club head assembly treated at 900 °C substantially maintained its bulge and roll curvature after 300 hits. In one embodiment, the club head assembly

treated at 900 °C substantially maintained its bulge and roll curvature after 500 hits. In one embodiment, the club head assembly treated at 900 °C substantially maintained its bulge and roll curvature after 1,000 hits. In one embodiment, the club head assembly treated at 900 °C substantially maintained its bulge and roll curvature after 1500 hits. In one embodiment, the club head assembly treated at 900 °C substantially maintained its bulge and roll curvature after 2,000 hits.

[0081] In one embodiment, the club head assembly treated at 1000 °C maintained its original bulge and roll curvature after 25 hits. In one embodiment, the club head assembly treated at 1000 °C maintained its original bulge and roll curvature after 50 hits. In one embodiment, the club head assembly treated at 1000 °C maintained its original bulge and roll curvature after 75 hits. In one embodiment, the club head assembly treated at 1000 °C maintained its original bulge and roll curvature after 100 hits. In one embodiment, the club head assembly treated at 1000 °C maintained its original bulge and roll curvature after 125 hits. In one embodiment, the club head assembly treated at 1000 °C maintained its original bulge and roll curvature after 150 hits. In one embodiment, the club head assembly treated at 1000 °C maintained its original bulge and roll curvature after 175 hits. In one embodiment, the club head assembly treated at 1000 °C maintained its original bulge and roll curvature after 200 hits. In one embodiment, the club head assembly treated at 1000 °C maintained its original bulge and roll curvature after 225 hits.

[0082] In one embodiment, the club head assembly treated at 1000 °C substantially maintained its bulge and roll curvature after 250 hits. In one embodiment, the club head assembly treated at 1000 °C substantially maintained its bulge and roll curvature after 275 hits. In one embodiment, the club head assembly treated at 1000 °C substantially maintained its bulge and roll curvature after 300 hits. In one embodiment, the club head assembly treated at 1000 °C substantially maintained its bulge and roll curvature after 500 hits. In one embodiment, the club head assembly treated at 1000 °C substantially maintained its bulge and roll curvature after 1,000 hits. In one embodiment, the club head assembly treated at 1000 °C substantially maintained its bulge and roll curvature after 1500 hits. In one embodiment, the club head assembly treated at 1000 °C substantially maintained its bulge and roll curvature after 2,000 hits.

[0083] In one embodiment, the club head assembly treated at 1100 °C maintained its original bulge and roll curvature after 25 hits. In one embodiment, the club head assembly treated at 1100 °C maintained its original bulge and roll curvature after 50 hits. In one embodiment, the club head assembly treated at 1100 °C maintained its original bulge and roll curvature after 75 hits. In one embodiment, the club head assembly treated at 1100 °C maintained its original bulge and roll curvature after 100 hits. In one embodiment, the club head assembly treated at 1100 °C maintained its original bulge and roll curvature after 125 hits. In one embodiment, the club head assembly treated at 1100 °C maintained its original bulge and roll curvature after 150 hits. In one embodiment, the club head assembly treated at 1100 °C maintained its original bulge and roll curvature after 175 hits. In one embodiment, the club head assembly treated at 1100 °C maintained its original bulge and roll curvature after 200 hits. In one embodiment, the club head assembly treated at 1100 °C maintained its original bulge and roll curvature after 225 hits.

[0084] In one embodiment, the club head assembly treated at 1100 °C substantially maintained its bulge and roll curvature after 250 hits. In one embodiment, the club head assembly treated at 1100 °C substantially maintained its bulge and roll curvature after 275 hits. In one embodiment, the club head assembly treated at 1100 °C substantially maintained its bulge and roll curvature after 300 hits. In one embodiment, the club head assembly treated at 1100 °C substantially maintained its bulge and roll curvature after 500 hits. In one embodiment, the club head assembly treated at 1100 °C substantially maintained its bulge and roll curvature after 1,000 hits. In one embodiment, the club head assembly treated at 1100 °C substantially maintained its bulge and roll curvature after 1500 hits. In one embodiment, the club head assembly treated at 1100 °C substantially maintained its bulge and roll curvature after 2,000 hits.

[0085] In one embodiment, the club head assembly treated at 1200 °C maintained its original bulge and roll curvature after 25 hits. In one embodiment, the club head assembly treated at 1200 °C maintained its original bulge and roll curvature after 50 hits. In one embodiment, the club head assembly treated at 1200 °C maintained its original bulge and roll curvature after 75 hits. In one embodiment, the club head assembly treated at 1200 °C maintained its original bulge and roll curvature after 100 hits. In one embodiment, the club head assembly treated at 1200 °C maintained its original bulge and roll curvature

after 125 hits. In one embodiment, the club head assembly treated at 1200 °C maintained its original bulge and roll curvature after 150 hits. In one embodiment, the club head assembly treated at 1200 °C maintained its original bulge and roll curvature after 175 hits. In one embodiment, the club head assembly treated at 1200 °C maintained its original bulge and roll curvature after 200 hits. In one embodiment, the club head assembly treated at 1200 °C maintained its original bulge and roll curvature after 225 hits.

[0086] In one embodiment, the club head assembly treated at 1200 °C substantially maintained its bulge and roll curvature after 250 hits. In one embodiment, the club head assembly treated at 1200 °C substantially maintained its bulge and roll curvature after 275 hits. In one embodiment, the club head assembly treated at 1200 °C substantially maintained its bulge and roll curvature after 300 hits. In one embodiment, the club head assembly treated at 1200 °C substantially maintained its bulge and roll curvature after 500 hits. In one embodiment, the club head assembly treated at 1200 °C substantially maintained its bulge and roll curvature after 1,000 hits. In one embodiment, the club head assembly treated at 1200 °C substantially maintained its bulge and roll curvature after 1500 hits. In one embodiment, the club head assembly treated at 1200 °C substantially maintained its bulge and roll curvature after 2,000 hits.

[0087] In one embodiment, the club head assembly treated at or above the solvus temperature maintained its original bulge and roll curvature after 25 hits. In one embodiment, the club head assembly treated at or above the solvus temperature maintained its original bulge and roll curvature after 50 hits. In one embodiment, the club head assembly treated at or above the solvus temperature maintained its original bulge and roll curvature after 75 hits. In one embodiment, the club head assembly treated at or above the solvus temperature maintained its original bulge and roll curvature after 100 hits. In one embodiment, the club head assembly treated at or above the solvus temperature maintained its original bulge and roll curvature after 125 hits. In one embodiment, the club head assembly treated at or above the solvus temperature maintained its original bulge and roll curvature after 150 hits. In one embodiment, the club head assembly treated at or above the solvus temperature maintained its original bulge and roll curvature after 175 hits. In one embodiment, the club head assembly treated at or above the solvus temperature maintained its original bulge and roll curvature after 200 hits. In one embodiment, the

club head assembly treated at or above the solvus temperature maintained its original bulge and roll curvature after 225 hits.

[0088] In one embodiment, the club head assembly treated at or above the solvus temperature substantially maintained its bulge and roll curvature after 250 hits. In one embodiment, the club head assembly treated at or above the solvus temperature substantially maintained its bulge and roll curvature after 275 hits. In one embodiment, the club head assembly treated at or above the solvus temperature substantially maintained its bulge and roll curvature after 300 hits. In one embodiment, the club head assembly treated at or above the solvus temperature substantially maintained its bulge and roll curvature after 500 hits. In one embodiment, the club head assembly treated at or above the solvus temperature substantially maintained its bulge and roll curvature after 1,000 hits. In one embodiment, the club head assembly treated at or above the solvus temperature substantially maintained its bulge and roll curvature after 1500 hits. In one embodiment, the club head assembly treated at or above the solvus temperature substantially maintained its bulge and roll curvature after 2,000 hits.

[0089] Also, as shown in FIG. 8, a follow-up experiment was performed to compare the impact of a 600 °C heat treatment on three different faceplate geometries. The roll measurements for all three faceplate geometries were consistent, confirming that the stress-relief heat treatment increases the faceplate's ability to maintain its curvature. The faceplate comprised the Ti-9S (or T-9S) alloy.

[0090] Referring now to FIG. 9, an experiment was performed to compare the effect of various heat treatment temperatures on the faceplate 14 over the course of 2,000 hits or ball strikes. The faceplates 14 were formed from Ti-9S (or T-9S) alloy. One club head assembly was heated to 550 °C, which is below the solvus temperature of the Ti-9S (or T-9S) alloy. A second club head assembly was heated to 575 °C and a third club head was heated to 600 °C, which is above the solvus temperature of the Ti-9S (or T-9S) alloy. The measurement data provided in FIG. 9 represent the percentage change in the radius of curvature of the bulge and the roll dimensions compared to the original radius curvature. As the faceplate becomes more flat, the radius of curvature increases. The club head assembly treated at 550 °C flattened significantly in both its roll and bulge dimensions within a few hits on a golf ball.

In contrast, the club head assembly treated at 600 °C maintained its curvature significantly better than the club head assemblies after 2,000 hits.

[0091] In one embodiment, the faceplate 14 formed from Ti-9S (or T-9S) and heat treated at 600 °C remains within 1% deflection of its original roll curvature and within 3% deflection of its original bulge curvature after 25 strikes. In one embodiment, the faceplate 14 formed from Ti-9S (or T-9S) and heat treated at 575 °C remains within 24% deflection of its original roll curvature and within 11% deflection of its original bulge curvature after 25 strikes. In one embodiment, the faceplate 14 formed from Ti-9S (or T-9S) and heat treated at 550 °C remains within 19% deflection of its original roll curvature and within 9% deflection of its original bulge curvature after 25 strikes.

[0092] In one embodiment, the faceplate 14 formed from Ti-9S (or T-9S) and heat treated at 600 °C retains its original roll curvature and is within 4% deflection of its original bulge curvature after 50 strikes. In one embodiment, the faceplate 14 formed from Ti-9S (or T-9S) and heat treated at 575 °C remains within 28% deflection of its original roll curvature and within 13% deflection of its original bulge curvature after 50 strikes. In one embodiment, the faceplate 14 formed from Ti-9S (or T-9S) and heat treated at 550 °C remains within 23% deflection of its original roll curvature and within 15% deflection of its original bulge curvature after 50 strikes.

[0093] In one embodiment, the faceplate 14 formed from Ti-9S (or T-9S) and heat treated at 600 °C retains its original roll curvature and is within 5% deflection of its original bulge curvature after 75 strikes. In one embodiment, the faceplate 14 formed from Ti-9S (or T-9S) and heat treated at 575 °C remains within 28% deflection of its original roll curvature and within 12% deflection of its original bulge curvature after 75 strikes. In one embodiment, the faceplate 14 formed from Ti-9S (or T-9S) and heat treated at 550 °C remains within 28% deflection of its original roll curvature and within 23% deflection of its original bulge curvature after 75 strikes.

[0094] In one embodiment, the faceplate 14 formed from Ti-9S (or T-9S) and heat treated at 600 °C retains its original roll curvature and is within 6% deflection of its original bulge curvature after 100 strikes. In one embodiment, the faceplate 14 formed from Ti-9S (or T-9S) and heat treated at 575 °C remains within 30% deflection of its original roll curvature and within 13% deflection of its original bulge curvature after 100 strikes. In one embodiment,

the faceplate 14 formed from Ti-9S (or T-9S) and heat treated at 550 °C remains within 29% deflection of its original roll curvature and within 22% deflection of its original bulge curvature after 100 strikes.

[0095] In one embodiment, the faceplate 14 formed from Ti-9S (or T-9S) and heat treated at 600 °C retains its original roll curvature and is within 7% deflection of its original bulge curvature after 150 strikes. In one embodiment, the faceplate 14 formed from Ti-9S (or T-9S) and heat treated at 575 °C remains within 28% deflection of its original roll curvature and within 13% deflection of its original bulge curvature after 150 strikes. In one embodiment, the faceplate 14 formed from Ti-9S (or T-9S) and heat treated at 550 °C remains within 31% deflection of its original roll curvature and within 24% deflection of its original bulge curvature after 150 strikes.

[0096] In one embodiment, the faceplate 14 formed from Ti-9S (or T-9S) and heat treated at 600 °C remains within 5% deflection of its original roll curvature and within 5% deflection of its original bulge curvature after 300 strikes. In one embodiment, the faceplate 14 formed from Ti-9S (or T-9S) and heat treated at 575 °C remains within 28% deflection of its original roll curvature and within 14% deflection of its original bulge curvature after 300 strikes. In one embodiment, the faceplate 14 formed from Ti-9S (or T-9S) and heat treated at 550 °C remains within 34% deflection of its original roll curvature and within 26% deflection of its original bulge curvature after 300 strikes.

[0097] In one embodiment, the faceplate 14 formed from Ti-9S (or T-9S) and heat treated at 600 °C remains within 4% deflection of its original roll curvature and within 7% deflection of its original bulge curvature after 1,000 strikes. In one embodiment, the faceplate 14 formed from Ti-9S (or T-9S) and heat treated at 575 °C remains within 27% deflection of its original roll curvature and within 13% deflection of its original bulge curvature after 1,000 strikes. In one embodiment, the faceplate 14 formed from Ti-9S (or T-9S) and heat treated at 550 °C remains within 34% deflection of its original roll curvature and within 27% deflection of its original bulge curvature after 1,000 strikes.

[0098] In one embodiment, the faceplate 14 formed from Ti-9S (or T-9S) and heat treated at 600 °C remains within 5% deflection of its original roll curvature and within 6% deflection of its original bulge curvature after 2,000 strikes. In one embodiment, the faceplate 14 formed from Ti-9S (or T-9S) and heat treated at 575 °C remains within 25% deflection of its

original roll curvature and within 15% deflection of its original bulge curvature after 2,000 strikes. In one embodiment, the faceplate 14 formed from Ti-9S (or T-9S) and heat treated at 550 °C remains within 34% deflection of its original roll curvature and within 28% deflection of its original bulge curvature after 2,000 strikes.

[0099] As shown in FIG. 10, an experiment was performed to compare the durability of faceplate 14 when composed of either the Ti-6-4 alloy or the Ti-9S (T-9S) alloy. The experiment tracked the number of strikes from an air cannon until failure of the faceplate 14. One club head assembly used Ti 6-4 alloy as the faceplate material. A second club head assembly used a different model club head with Ti 6-4 alloy as the faceplate material (data not shown). A third club head assembly used a third model club head with the Ti 6-4 alloy as the faceplate material (data not shown). A fourth club head assembly uses the same model club head as the third club head assembly, with T-9S (or Ti-9S) alloy as the faceplate material. The measurement data provided in FIG. 10 represents the number of hits until failure of the faceplate. The club head assembly with the T-9S (or Ti-9S) alloy faceplate showed increased durability over assemblies with Ti 6-4 alloy faceplates. The same club head model showed an increased durability of about 3200 hits until failure of the faceplate with T-9S (or Ti-9S) alloy as the faceplate material, as opposed to a durability of 2600 hits until failure with Ti 6-4 alloy as the faceplate material.

[00100] Table 1, shown below, quantifies the composition of T-9S, Ti 6-4, and Ti-8-1-1 alloys. Table 2, shown below, is a chart showing the mechanical properties of various α-β Ti alloys. This data is based on METL reports and verified with industry standards and supplier data sheets. Table 3 is a chart showing the projected weight savings based on one embodiment.

Table 1. Chart showing the compositions of T-9S, Ti 6-4, and Ti-8-1-1.

	C	Si	Mo	Fe	Al	V	Sn	O	Ti
9s	0.08 max	0.20 max	trace	0.30 max	6.50 - 8.50	1.00 - 2.00	trace	0.20 max	balance
6-4	0.08 max	0.03 max	trace	0.30 max	5.50 - 6.75	3.50 - 4.50	0.015 max	0.20 max	balance
8-1-1	0.08 max	trace	0.75 - 1.25	0.30 max	7.50 - 8.50	0.75 - 1.25	0.015 max	0.12 max	balance

Table 2. Chart showing the mechanical properties of various α-β Ti alloys.

	T9S Sheet * (transverse)	T9S Sheet * (longitudinal)	Ti 6-4 Cast	Ti 6-4 Sheet	Ti 8-1-1 Cast	Ti 8-1-1 Sheet	17-4 Sheet Cond A
Yield (ksi)	135 - 145	135 -145	115 -125	125 -135	110 -120	115 -125	130 - 140
Tensile (ksi)	145 - 155	155 -165	125-135	130-140	125 -135	125 -135	150 - 160
Elongation (%)	7 - 12	14 - 19	13 - 18	12 - 15	7 - 12	8 - 10	4 - 6
Young's Modulus (Mpsi)	15.9	15.2	16.2	16.5	18.0	17.5	28.5

** Samples had driver heat treat (600°C for 1 hour)*

Table 3. Chart showing the projected weight savings based on the a selected embodiment.

	Outer Face Thickness	Center Face Thickness	Density		Face Volume	Face Mass	Wt Savings Over Ti 6-4	Body Volume	Body Mass
	(inches)	(inches)	(lb/in^3)	(g/in^3)	(in^3)	(grams)	(grams)	(in^3)	(grams)
Ti 6-4 (current)	0.090	0.140	0.1597	72.44	0.592	42.9	---	1.9013	137.7
Ti 8-1-1	0.090	0.140	0.1575	71.44	0.592	42.3	0.6	1.9013	135.8
T9S	0.090	0.140	0.1560	70.76	0.592	**41.9**	**1.0**	1.9013	134.5
T9S @ 5% thinner	0.086	0.136	0.1560	70.76	0.563	**39.8**	**3.1**	1.9013	134.5
T9S @ 10% thinner	0.081	0.131	0.1560	70.76	0.533	**37.7**	**5.2**	1.9013	134.5

[00101] FIG. 11A shows the grains in the microstructure of an α-β Ti alloy that has not been through heat treat. Distinct striations of β bands can be seen among pockets of the α/β matrix. In contrast, FIG. 11B shows the grains in the microstructure of an α-β Ti alloy that has been through heat treat. Here, the grains show directionality in the crown-to-sole direction. The corresponding stress-strain curves of the no heat treat and heat treated samples, FIGS. 12C and 12D, show the benefits of heat treat. The stress/strain curve of the non-heat treated α-β Ti alloy (FIG. 11C) shows unstable yielding at high strain rates, most likely due to deformation of β bands. The β bands are known to have a different plasticity value compared to the α/β matrix, which causes the aforementioned deformation at high strain

rates. The stress/strain curve of the heat treated α-β Ti alloy (FIG. 11D) is more stable and attests to stresses transferring more easily along grain boundaries at high strain rates.

[00102] FIG. 12 shows the phase diagram of Ti and Al alloys. The $\alpha+Ti_3Al$ shaded region represents α-β Ti alloys which have not yet undergone heat treatment. $\alpha+Ti_3Al$ is brittle material unsuitable for faceplate manufacturing. When $\alpha+Ti_3Al$ is heated above its solvus temperature, indicated via the vertical line, it changes to αTi phase. During this transition, the Ti_3Al in the $\alpha+Ti_3Al$ goes into solution and relieves the brittle properties of $\alpha+Ti_3Al$. As shown in the diagram, the temperature change for this transition depends on the percent of aluminum in the $\alpha+Ti_3Al$.

[00103] As shown in FIG. 13, an experiment was performed to compare the amount of deflection of various faceplates 14 over the course of 0, 25, 50, 100, 150, 1000, and 2,000 hits or ball strikes. The faceplates 14 were formed from Ti 6-4 or Ti-9S (T-9S) alloy. One club head assembly made of Ti 6-4 alloy was not heat treated. A second club head assembly made of Ti6-4 alloy was heated to 600 °C, which is above the solvus temperature of the Ti-9S (or T-9S) alloy. A third club head assembly made of the the Ti-9S (or T-9S) alloy was heated to 600 °C, which is above the solvus temperature of the Ti-9S (or T-9S) alloy. The measurement data provided in Table 4, shown below, represent the percent change in the radius of curvature of the bulge and the roll dimensions compared to the original radius curvature.

Table 4. Raw data for the percentage deflection of the roll and bulge on Ti 6-4 alloys with and without heat treat and T-9S alloys with heat treat.

Hits	Ti 6-4 No HT Roll	Ti 6-4 No HT Bulge	Ti 6-4 600°C Roll	Ti 6-4 600°C Bulge	T9S 600°C Roll	T9S 600°C Bulge
0	0%	0%	0%	0%	0%	0%
25	2%	7%	10%	4%	0%	1%
50	4%	8%	12%	6%	8%	7%
100	13%	9%	16%	7%	8%	8%
150	13%	10%	19%	11%	8%	8%
1000	21%	16%	25%	15%	9%	8%
2000	22%	17%	30%	15%	10%	10%

[00104] As the faceplate becomes more flat, the radius of curvature increases. The club head assembly having a faceplate 14 made of Ti 6-4 treated at 600 °C flattened significantly

in both its roll and bulge dimensions and did not perform like the club head assembly having a faceplate 14 made of T9S treated at 600 °C which stayed below 10% deflection in both its roll and bulge dimensions for all number of hits up to 2,000. This may be due to Ti 6-4 having a different or lower wt% Al content; T9S has 6.5wt%-8.5wt% Al and Ti 6-4 has 5.5 wt%-6.75 wt% Al. The solvus temperature for Ti 6-4 is lower at ~540-560 °C compared to the solvus temperature for T9S, which is ~560-590 °C. Therefore, the 600°C heat treat did not have the same effect on Ti 6-4 as it did on T9S. The Ti-9S faceplate treated at 600 °C maintained its' curvature better after 2000 hits than the club head assemblies having faceplates 14 of Ti-6-4 untreated and heat treated maintained curvature in both roll and bulge dimensions.

[00105] As shown in FIG. 15, an experiment was performed to compare the % deflection on the faceplate 14 over the course of 100 and 1000 hits or ball strikes. The faceplates 14 were formed from Ti 6-4 or Ti-9S (T-9S) alloy. The various club head assemblies were treated for either 1 or 4 hours at 400°C, 550°C, 575°C, 580°C, 600°C, and 700°C. One club head assembly made of Ti 6-4 alloy was not heat treated. A second club head assembly made of Ti-9S (or T-9S) alloy was not heat treated. A third club head assembly made of Ti-9S (or T-9S) alloy was heated for 1 hour to 400 °C, which is below the solvus temperature of the Ti-9S (or T-9S) alloy. A fourth club head assembly made of Ti-9S (or T-9S) alloy was heated for 1 hour to 550 °C, which is below the solvus temperature of the Ti-9S (or T-9S) alloy. A fifth club head assembly made of Ti-9S (or T-9S) alloy was heated for 1 hour to 575 °C, which is below the solvus temperature of the Ti-9S (or T-9S) alloy. A sixth club head assembly made of Ti-9S (or T-9S) alloy was heated for 4 hours to 580 °C, which is the solvus temperature of the Ti-9S (or T-9S) alloy. A seventh club head assembly made of Ti-9S (or T-9S) alloy was heated for 1 hour to 600°C, which is above the solvus temperature of the Ti-9S (or T-9S) alloy. A eighth club head assembly made of Ti-9S (or T-9S) alloy was heated for 4 hours to 600 °C, which is above the solvus temperature of the Ti-9S (or T-9S) alloy. A ninth club head assembly made of Ti-9S (or T-9S) alloy was heated for 1 hour to 700 °C, which is above the solvus temperature of the Ti-9S (or T-9S) alloy. A tenth club head assembly made of Ti-9S (or T-9S) alloy was heated for 4 hours to 700 °C, which is above the solvus temperature of the Ti-9S (or T-9S) alloy. The measurement data provided in FIG. 15 represent the percent change in the radius of curvature of the bulge and the roll dimensions compared to the original radius curvature. As the faceplate becomes more flat, the radius of curvature increases.

There is less deflection in roll and much more in bulge going from 575°C to 580°C. However, at slightly higher temperature (600°C and above), the percent deflection for both measurements drop significantly and then stays the same at even higher temperatures. This represents the inflection point where the Ti_3Al particles begin to enter the solution. After reaching the 600°C for 1 hour threshold, increasing the temperature does not give any significant improvements to geometric stability. Increasing the duration from 1 to 4 hours did not have a significant improvement on percent deflection either.

[00106] In one embodiment, the faceplate 14 that is formed from Ti-9S (or T-9S) and heat treated at the solvus temperature of Ti-9S (or T-9S), 580°C, for 4 hours, has ~9% deflection from its original bulge and ~6% deflection from its original roll curvature after about 100 strikes. In one embodiment, the faceplate 14 that is formed from Ti-9S (or T-9S) and heat treated at the solvus temperature of Ti-9S (or T-9S), 580°C, for 4 hours, has ~10% deflection from its original bulge and ~6% deflection from its original roll curvature after about 1000 strikes.

[00107] In one embodiment, the faceplate 14 that is formed from Ti-9S (or T-9S) and heat treated above the solvus temperature of Ti-9S (or T-9S), 600°C, for 1 hour, has ~5% deflection from its original bulge and ~3% deflection from its original roll curvature after about 100 strikes. In one embodiment, the faceplate 14 that is formed from Ti-9S (or T-9S) and heat treated above the solvus temperature of Ti-9S (or T-9S), 600°C, for 1 hour, has ~6% deflection from its original bulge and ~5% deflection from its original roll curvature after about 1000 strikes.

[00108] In one embodiment, the faceplate 14 that is formed from Ti-9S (or T-9S) and heat treated above the solvus temperature of Ti-9S (or T-9S), 600°C, for 4 hours, has ~5% deflection from its original bulge and ~2% deflection from its original roll curvature after about 100 strikes. In one embodiment, the faceplate 14 that is formed from Ti-9S (or T-9S) and heat treated above the solvus temperature of Ti-9S (or T-9S), 600°C, for 4 hours, has ~6% deflection from its original bulge and ~3% deflection from its original roll curvature after about 1000 strikes.

[00109] In one embodiment, the faceplate 14 that is formed from Ti-9S (or T-9S) and heat treated above the solvus temperature of Ti-9S (or T-9S), 700°C, for 1 hour, has ~4% deflection from its original bulge and ~3% deflection from its original roll curvature

after about 100 strikes. In one embodiment, the faceplate 14 that is formed from Ti-9S (or T-9S) and heat treated above the solvus temperature of Ti-9S (or T-9S), 700°C, for 1 hour, has ~5% deflection from its original bulge and ~3% deflection from its original roll curvature after about 1000 strikes.

[00110] In one embodiment, the faceplate 14 that is formed from Ti-9S (or T-9S) and heat treated above the solvus temperature of Ti-9S (or T-9S), 700°C, for 4 hours, has ~3% deflection from its original bulge and ~5% deflection from its original roll curvature after about 100 strikes.

[00111] In one embodiment, the faceplate 14 that is formed from an α-β Ti alloy and heat treated above its solvus temperature, 500-1200°C, has 30% or less deflection from its original bulge and 30% or less deflection from its original roll curvature after about 2000 strikes or less.

[00112] In one embodiment, the faceplate 14 that is formed from an α-β Ti alloy and heat treated at or above its solvus temperature has 30% or less deflection from its original bulge and 30% or less deflection from its original roll curvature after about 2000 strikes or less. In one embodiment, the faceplate 14 that is formed from an α-β Ti alloy and heat treated at or above its solvus temperature has 25% or less deflection from its original bulge and 25% or less deflection from its original roll curvature after about 2000 strikes or less. In one embodiment, the faceplate 14 that is formed from an α-β Ti alloy and heat treated at or above its solvus temperature has 20% or less deflection from its original bulge and 20% or less deflection from its original roll curvature after about 2000 strikes or less. In one embodiment, the faceplate 14 that is formed from an α-β Ti alloy and heat treated at or above its solvus temperature has 15% or less deflection from its original bulge and 15% or less deflection from its original roll curvature after about 2000 strikes or less. In one embodiment, the faceplate 14 that is formed from an α-β Ti alloy and heat treated at or above its solvus temperature has 10% or less deflection from its original bulge and 10% or less deflection from its original roll curvature after about 2000 strikes or less. In one embodiment, the faceplate 14 that is formed from an α-β Ti alloy and heat treated at or above its solvus temperature has 9% or less deflection from its original bulge and 9% or less deflection from its original roll curvature after about 2000 strikes or less. In one embodiment, the faceplate 14 that is formed from an α-β Ti alloy and heat treated at or above its solvus temperature has 8% or less deflection from

its original bulge and 8% or less deflection from its original roll curvature after about 2000 strikes or less. In one embodiment, the faceplate 14 that is formed from an α-β Ti alloy and heat treated at or above its solvus temperature has 7% or less deflection from its original bulge and 7% or less deflection from its original roll curvature after about 2000 strikes or less. In one embodiment, the faceplate 14 that is formed from an α-β Ti alloy and heat treated at or above its solvus temperature has 6% or less deflection from its original bulge and 6% or less deflection from its original roll curvature after about 2000 strikes or less. In one embodiment, the faceplate 14 that is formed from an α-β Ti alloy and heat treated at or above its solvus temperature has 5% or less deflection from its original bulge and 5% or less deflection from its original roll curvature after about 2000 strikes or less. In one embodiment, the faceplate 14 that is formed from an α-β Ti alloy and heat treated at or above its solvus temperature has 4% or less deflection from its original bulge and 4% or less deflection from its original roll curvature after about 2000 strikes or less. In one embodiment, the faceplate 14 that is formed from an α-β Ti alloy and heat treated at or above its solvus temperature has 3% or less deflection from its original bulge and 3% or less deflection from its original roll curvature after about 2000 strikes or less. In one embodiment, the faceplate 14 that is formed from an α-β Ti alloy and heat treated at or above its solvus temperature has 2% or less deflection from its original bulge and 2% or less deflection from its original roll curvature after about 2000 strikes or less. In one embodiment, the faceplate 14 that is formed from an α-β Ti alloy and heat treated at or above its solvus temperature has 1% or less deflection from its original bulge and 1% or less deflection from its original roll curvature after about 2000 strikes or less. In one embodiment, the faceplate 14 that is formed from an α-β Ti alloy and heat treated at or above its solvus temperature has 0% or less deflection from its original bulge and 0% or less deflection from its original roll curvature after about 2000 strikes or less.

[00113] Thus, the invention provides, among other things, a method of forming a golf club head assembly. Although the invention has been described in detail with reference to certain preferred embodiments, variations and modifications exist within the scope and spirit of one or more independent aspects of the invention as described.

[00114] Clause 1. A method of forming a golf club head assembly, the method comprising:

aligning a faceplate with a recess of a club head;

welding the faceplate to the club head;

after welding the faceplate, heating the club head and the faceplate to at least a solvus temperature of the faceplate for a predetermined amount of time; and

after heating the club head and the faceplate, allowing the club head and the faceplate to cool in an inert gas.

[00115] Clause 2. The method of clause 1, further comprising forming the faceplate from an α-β titanium alloy.

[00116] Clause 3. The method of clause 1, wherein welding the faceplate includes a pulse plasma welding process.

[00117] Clause 4. The method of clause 1, providing a faceplate with a minimum thickness of 0.7 mm.

[00118] Clause 5. The method of clause 1, wherein heating the club head and the faceplate includes heating the club head and the faceplate for between 1 hour and 6 hours.

[00119] Clause 6. The method of clause 5, wherein heating the club head and the faceplate includes heating the club head and the faceplate to between 400 °C and 630 °C or between 400 °C and 1200 °C.

[00120] Clause 7. The method of clause 6, wherein heating the club head and the faceplate includes heating the club head and the faceplate to between 475 °C and 625 °C or between 520 °C and 1150 °C for between 1 hour and 6 hours.

[00121] Clause 8. The method of clause 7, wherein heating the club head and the faceplate includes heating the club head and the faceplate to between 475 °C and 550 °C or between 520 °C and 1150 °C for between 4 hours and 6 hours.

[00122] Clause 9. The method of clause 8, wherein heating the club head and the faceplate includes heating the club head and the faceplate to between 475 °C and 500 °C or between 520 °C and 1100 °C for between 4 hours and 6 hours.

[00123] Clause 10. The method of clause 7, wherein heating the club head and the faceplate includes heating the club head and the faceplate to between 550 °C and 625 °C or between 620 °C and 1200 °C for between 1 hour and 2 hours.

[00124] Clause 11. The method of clause 10, wherein heating the club head and the faceplate includes heating the club head and the faceplate to between 575 °C and 625 °C or between 720 °C and 1200 °C for between 1 hour and 2 hours.

[00125] Clause 12. A method of forming a golf club head assembly, the method comprising:

providing a faceplate formed from an α-β titanium alloy, the alloy having a solvus temperature;

aligning the faceplate with a recess of a club head;

welding the faceplate to the club head;

after welding the faceplate, heating the club head and the faceplate to a temperature that is greater than the solvus temperature of the faceplate for a predetermined amount of time; and

after heating the club head and the faceplate, allowing the club head and the faceplate to air cool.

[00126] Clause 13. The method of clause 11, wherein welding the faceplate includes a pulse plasma welding process.

[00127] Clause 14. The method of clause 11, wherein heating the club head and the faceplate includes heating the club head and the faceplate for between 1 hour and 6 hours.

[00128] Clause 15. The method of clause 13, wherein heating the club head and the faceplate includes heating the club head and the faceplate to between 400 °C and 630 °C, between 400 °C and 1200 °C, between 500 °C and 1030 °C, between 680 °C and 1030 °C, between 760 °C and 1030 °C, between 870 °C and 1030 °C, between 890 °C and 1030 °C,or between 960 °C and 1030 °C.

[00129] Clause 16. The method of clause 15, wherein heating the club head and the faceplate includes heating the club head and the faceplate to between 475 °C and 625 °C or between 520 °C and 1200 °C for between 1 hour and 6 hours.

[00130] Clause 17. The method of clause 16, wherein heating the club head and the faceplate includes heating the club head and the faceplate to between 475 °C and 550 °C f or between 520 °C and 1150 °C or between 4 hours and 6 hours.

[00131] Clause 18. The method of clause 17, wherein heating the club head and the faceplate includes heating the club head and the faceplate to between 475 °C and 500 °C or between 520 °C and 1100 °C for between 4 hours and 6 hours.

[00132] Clause 19. The method of clause 15, wherein heating the club head and the faceplate includes heating the club head and the faceplate to between 550 °C and 625 °C or between 620 °C and 1200 °C for between 1 hour and 2 hours.

[00133] Clause 20. The method of clause 19, wherein heating the club head and the faceplate includes heating the club head and the faceplate to between 575 °C and 625 °C or between 720 °C and 1200 °C for between 1 hour and 2 hours.

[00134] Clause 21. The method of clause 12, wherein the faceplate is formed from an α-β Ti alloy with 7-20 wt% Al.

[00135] Clause 22. The method of clause 21, wherein the inert gas is selected from the group consisting of nitrogen (N), argon (Ar), helium (He), neon (Ne), krypton (Kr), and xenon (Xe) or a compound gas thereof.

[00136] Clause 23. The method of clause 22, wherein the inert gas is nitrogen (N) or argon (Ar) or a compound gas thereof.

[00137] Clause 24. A method of forming a golf club head assembly, the method comprising: (a) providing a faceplate formed from an α-β titanium alloy, the α-β titanium alloy comprising between 6.5wt% to 20wt% aluminum (Al), 1.0wt% to 2.0wt% vanadium (V), 0.20wt% or less oxygen (O), and 0.20wt% or less silicon (Si); (b) aligning the faceplate with a recess of a club head; (c) welding the faceplate to the club head; (d) heating the club head and the faceplate to a temperature that is greater than the solvus temperature of the faceplate for a predetermined amount of time; and (e) allowing the club head and the faceplate to cool in an inert gas, wherein step (d) is performed between 520 °C and 1200 °C for between 1 hour and 6 hours.

[00138] Clause 25. The method of clause 24, wherein the α-β titanium alloy further comprises 0.30wt% or less iron (Fe), 0.08wt% or less carbon (C), 0.05wt% or less nitrogen (N), trace molybdenum (Mo), trace tin (Sn), and the remaining weight percent is titanium (Ti).

[00139] Clause 26. The method of clause 24, wherein the welding of step (c) includes a pulse plasma welding process.

[00140] Clause 27. The method of clause 24, wherein the inert gas of step (e) is selected from the group consisting of nitrogen (N), argon (Ar), helium (He), neon (Ne), krypton (Kr), and xenon (Xe) or a compound gas thereof.

[00141] Clause 28. The method of clause 27, wherein the inert gas is nitrogen (N) or argon (Ar).

[00142] Clause 29. The method of clause 24, wherein the faceplate of step (a) has a minimum thickness of 0.7 mm.

[00143] Clause 30. The method of clause 24, wherein step (d) includes heating the club head and the faceplate between 550 °C and 1200 °C for between 1 hour and 2 hours.

[00144] Clause 31. The method of clause 30, wherein heating the club head and the faceplate includes heating the club head and the faceplate to between 575 °C and 1200 °C for between 1 hour and 2 hours.

[00145] Clause 32. A method of forming a golf club head assembly, the method comprising:providing a faceplate formed from an α-β titanium alloy, the α-β titanium alloy comprising between 6.5wt% to 20wt% aluminum (Al), 1.0wt% to 2.0wt% vanadium (V), 0.20wt% or less oxygen (O), 0.20wt% or less silicon (Si), 0.30wt% or less iron (Fe), 0.08wt% or less carbon (C), 0.05wt% or less nitrogen (N), trace molybdenum (Mo), trace tin (Sn), and the remaining weight percent is titanium (Ti); aligning the faceplate with a recess of a club head;welding the faceplate to the club head; after welding the faceplate, heating the club head and the faceplate to a temperature that is greater than the solvus temperature of the faceplate for a predetermined amount of time; and after heating the club head and the faceplate, allowing the club head and the faceplate to cool in an inert gas environment.

[00146] Clause 33. The method of clause 32, wherein welding the faceplate includes a pulse plasma welding process.

[00147] Clause 34. The method of clause 32, wherein heating the club head and the faceplate includes heating the club head and the faceplate for between 1 hour and 6 hours.

[00148] Clause 35. The method of clause 34, wherein heating the club head and the faceplate includes heating the club head and the faceplate to between 520 °C and 1200 °C.

[00149] Clause 36. The method of clause 35, wherein heating the club head and the faceplate includes heating the club head and the faceplate to between 520 °C and 1200 °C for between 1 hour and 6 hours.

[00150] Clause 37. The method of clause 36, wherein heating the club head and the faceplate includes heating the club head and the faceplate to between 520 °C and 1150 °C for between 4 hours and 6 hours.

[00151] Clause 38. The method of clause 37, wherein heating the club head and the faceplate includes heating the club head and the faceplate to between 520 °C and 1100 °C for between 4 hours and 6 hours.

[00152] Clause 39. The method of clause 35, wherein heating the club head and the faceplate includes heating the club head and the faceplate to between 550 °C and 1200 °C for between 1 hour and 2 hours.

[00153] Clause 40. The method of clause 39, wherein heating the club head and the faceplate includes heating the club head and the faceplate to between 575 °C and 1200 °C for between 1 hour and 2 hours.

[00154] Clause 41. The method of clause 32, wherein the inert gas of step (e) is selected from the group consisting of nitrogen (N), argon (Ar), helium (He), neon (Ne), krypton (Kr), and xenon (Xe) or a compound gas thereof.

[00155] Clause 42. The method of clause 41 wherein the inert gas is nitrogen (N) or argon (Ar).

[00156] Clause 43. The method of clause 32, wherein the faceplate of step (a) with a minimum thickness of 0.7 mm.

[00157] Clause 44. A golf club head comprising: a crown, a sole; a toe end; a heel end; a recess positioned between the crown and the sole, and between the toe and heel ends; a hosel positioned adjacent to the heel end; a faceplate that is aligned with the recess and welded to the club head, the faceplate having a bulge curvature extending between the heel end and the toe end, the faceplate including an α-β titanium alloy comprising between 6.5wt% to 20wt% aluminum (Al), 1.0wt% to 2.0wt% vanadium (V), 0.20wt% or less oxygen (O), 0.20wt% or less silicon (Si), 0.30wt% or less iron (Fe), 0.08wt% or less carbon (C), 0.05wt% or less nitrogen (N), trace molybdenum (Mo), trace tin (Sn), and the remaining weight percent is titanium (Ti); wherein after the faceplate is welded to the club head, the club head and the faceplate are heated between 525 °C and 1200 °C for between 1 hour and 6 hour; and allowed to cool in an inert gas.

[00158] Clause 45. An α-β titanium alloy, the α-β titanium alloy comprising between 7wt% to 20wt% aluminum (Al), 1.0wt% to 2.0wt% vanadium (V), 0.20wt% or less oxygen (O), and 0.20wt% or less silicon (Si).

[00159] Clause 46. The alloy of claim 45, comprising between 7wt% to 13wt% aluminum (Al).

[00160] Clause 47. The alloy of claim 45, comprising between 8.5wt% to 13wt% aluminum (Al).

[00161] Clause 48. The alloy of claim 45, comprising between 10wt% to 13wt% aluminum (Al).

[00162] Clause 49. The alloy of claim 45, comprising between 11wt% to 13wt% aluminum (Al).

[00163] Clause 50. The alloy of any one of claims 45-49, comprising between 0.30wt% or less iron (Fe), 0.08wt% or less carbon (C), 0.05wt% or less nitrogen (N), trace molybdenum (Mo), trace tin (Sn), and the remaining weight percent is titanium (Ti).

CLAIMS

1. A method of forming a golf club head assembly, the method comprising:

(a) providing a faceplate formed from an α-β titanium alloy, the α-β titanium alloy comprising between 6.5wt% to 20wt% aluminum (Al), 1.0wt% to 2.0wt% vanadium (V), 0.20wt% or less oxygen (O), and 0.20wt% or less silicon (Si);

(b) aligning the faceplate with a recess of a club head;

(c) welding the faceplate to the club head;

(d) heating the club head and the faceplate to a temperature that is greater than the solvus temperature of the faceplate for a predetermined amount of time; and

(e) allowing the club head and the faceplate to cool in an inert gas,

wherein step (d) is performed between 525 °C and 1200 °C for between 1 hour and 6 hours.

2. A method of forming a golf club head assembly, the method comprising:
The method of claim 1, wherein the α-β titanium alloy comprises between 7wt% to 13wt% aluminum (Al).

3. A method of forming a golf club head assembly, the method comprising:
The method of claim 1, wherein the α-β titanium alloy comprises between 8.5wt% to 13wt% aluminum (Al).

4. A method of forming a golf club head assembly, the method comprising:
The method of claim 1, wherein the α-β titanium alloy comprises between 10wt% to 13wt% aluminum (Al).

5. The method of claim 1, wherein the α-β titanium alloy further comprises 0.30wt% or less iron (Fe), 0.08wt% or less carbon (C), 0.05wt% or less nitrogen (N), trace molybdenum (Mo), trace tin (Sn), and the remaining weight percent is titanium (Ti).

6. The method of claim 1, wherein the welding of step (c) includes a pulse plasma welding process.

7. The method of claim 1, wherein the inert gas of step (e) is selected from the group consisting of nitrogen (N), argon (Ar), helium (He), neon (Ne), krypton (Kr), and xenon (Xe) or a compound gas thereof.

8. The method of claim 4, wherein the inert gas is nitrogen (N) or argon (Ar).

9. The method of claim 1, wherein the faceplate of step (a) has a minimum thickness of 0.7 mm.

10. The method of claim 1, wherein step (d) includes heating the club head and the faceplate between 550 °C and 1200 °C for between 1 hour and 2 hours.

11. The method of claim 10, wherein heating the club head and the faceplate includes heating the club head and the faceplate to between 575 °C and 1200 °C for between 1 hour and 2 hours.

12. A method of forming a golf club head assembly, the method comprising: providing a faceplate formed from an α-β titanium alloy, the α-β titanium alloy comprising between 6.5wt% to 20wt% aluminum (Al), 1.0wt% to 2.0wt% vanadium (V), 0.20wt% or less oxygen (O), 0.20wt% or less silicon (Si), 0.30wt% or less iron (Fe), 0.08wt% or less carbon (C), 0.05wt% or less nitrogen (N), trace molybdenum (Mo), trace tin (Sn), and the remaining weight percent is titanium (Ti);

aligning the faceplate with a recess of a club head;

welding the faceplate to the club head;

after welding the faceplate, heating the club head and the faceplate to a temperature that is greater than the solvus temperature of the faceplate for a predetermined amount of time; and

after heating the club head and the faceplate, allowing the club head and the faceplate to cool in an inert gas environment.

13. The method of claim 12, wherein welding the faceplate includes a pulse plasma welding process.

14. The method of claim 12, wherein heating the club head and the faceplate includes heating the club head and the faceplate for between 1 hour and 6 hours.

15. The method of claim 14, wherein heating the club head and the faceplate includes heating the club head and the faceplate to between 520 °C and 1200 °C.

16. The method of claim 15, wherein heating the club head and the faceplate includes heating the club head and the faceplate to between 520 °C and 1200 °C for between 1 hour and 6 hours.

17. The method of claim 16, wherein heating the club head and the faceplate includes heating the club head and the faceplate to between 520 °C and 1150 °C for between 4 hours and 6 hours.

18. The method of claim 17, wherein heating the club head and the faceplate includes heating the club head and the faceplate to between 520 °C and 1100 °C for between 4 hours and 6 hours.

19. The method of claim 15, wherein heating the club head and the faceplate includes heating the club head and the faceplate to between 550 °C and 1200 °C for between 1 hour and 2 hours.

20. The method of claim 19, wherein heating the club head and the faceplate includes heating the club head and the faceplate to between 575 °C and 1200 °C for between 1 hour and 2 hours.

21. The method of claim 20, wherein the inert gas of step (e) is selected from the group consisting of nitrogen (N), argon (Ar), helium (He), neon (Ne), krypton (Kr), and xenon (Xe) or a compound gas thereof.

22. The method of claim 21, wherein the inert gas is nitrogen (N) or argon (Ar).

23. The method of claim 1, wherein the faceplate of step (a) with a minimum thickness of 0.7 mm.

24. A golf club head comprising:

a crown,

a sole;

a toe end;

a heel end;

a recess positioned between the crown and the sole, and between the toe and heel ends;

a hosel positioned adjacent to the heel end;

a faceplate that is aligned with the recess and welded to the club head, the faceplate having a roll curvature positioned between the crown and the toe end, the faceplate including an α-β titanium alloy comprising between 6.5wt% to 20wt% aluminum (Al), 1.0wt% to 2.0wt% vanadium (V), 0.20wt% or less oxygen (O), 0.20wt% or less silicon (Si), 0.30wt% or less iron (Fe), 0.08wt% or less carbon (C), 0.05wt% or less nitrogen (N), trace molybdenum (Mo), trace tin (Sn), and the remaining weight percent is titanium (Ti);

wherein after the faceplate is welded to the club head, the club head and the faceplate are heated between 525°C and 1200°C for between 1 hour and 6 hour; and allowed to cool in an inert gas.

25. An α-β titanium alloy, the α-β titanium alloy comprising between 7wt% to 20wt% aluminum (Al), 1.0wt% to 2.0wt% vanadium (V), 0.20wt% or less oxygen (O), and 0.20wt% or less silicon (Si).

26. The alloy of claim 25, comprising between 7wt% to 13wt% aluminum (Al).

27. The alloy of claim 25, comprising between 8.5wt% to 13wt% aluminum (Al).

28. The alloy of claim 25, comprising between 10wt% to 13wt% aluminum (Al).

29. The alloy of claim 25, comprising between 11wt% to 13wt% aluminum (Al).

30. The alloy of any one of claims 25-29, comprising between 0.30wt% or less iron (Fe), 0.08wt% or less carbon (C), 0.05wt% or less nitrogen (N), trace molybdenum (Mo), trace tin (Sn), and the remaining weight percent is titanium (Ti).

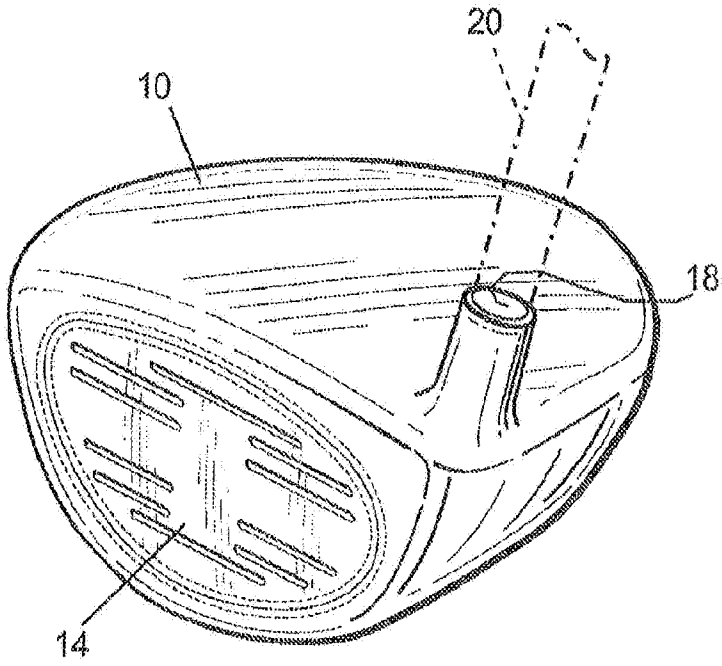


FIG. 1

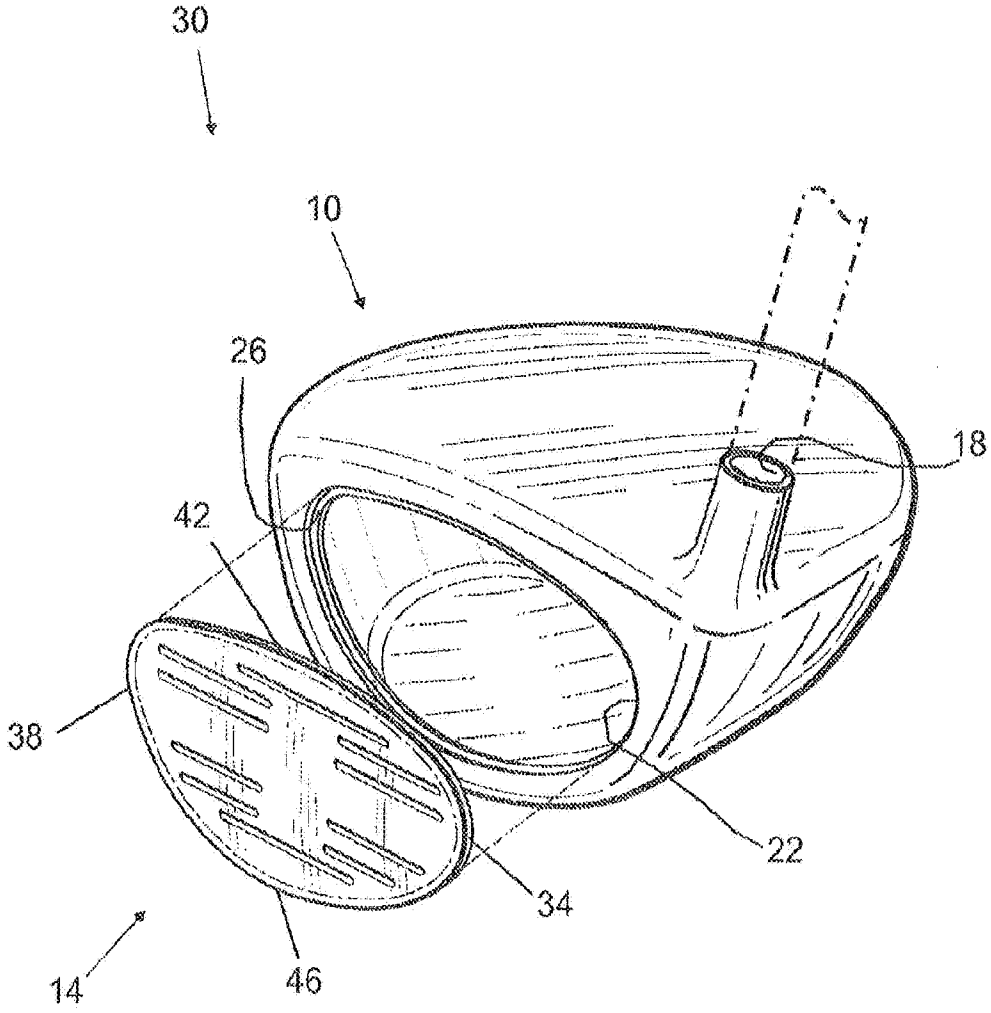


FIG. 2

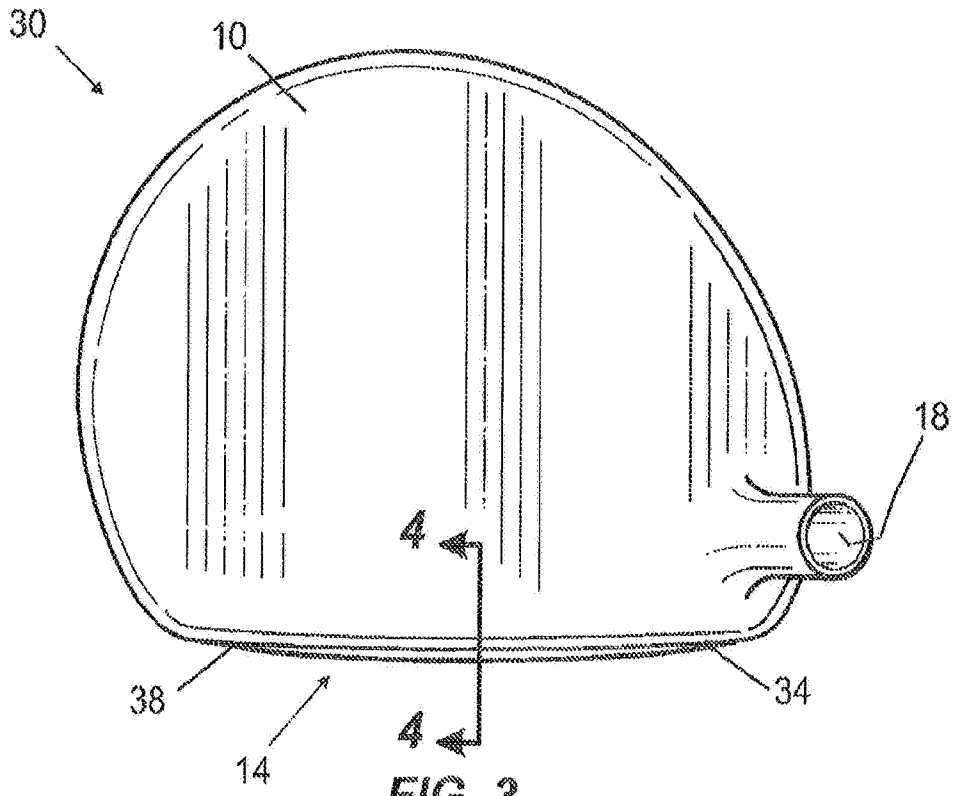


FIG. 3

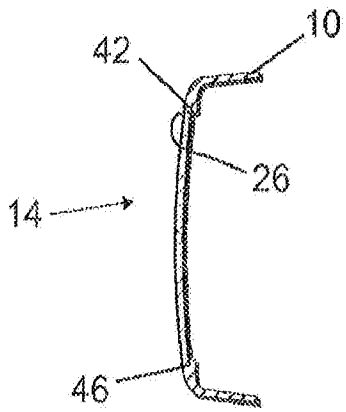


FIG. 4

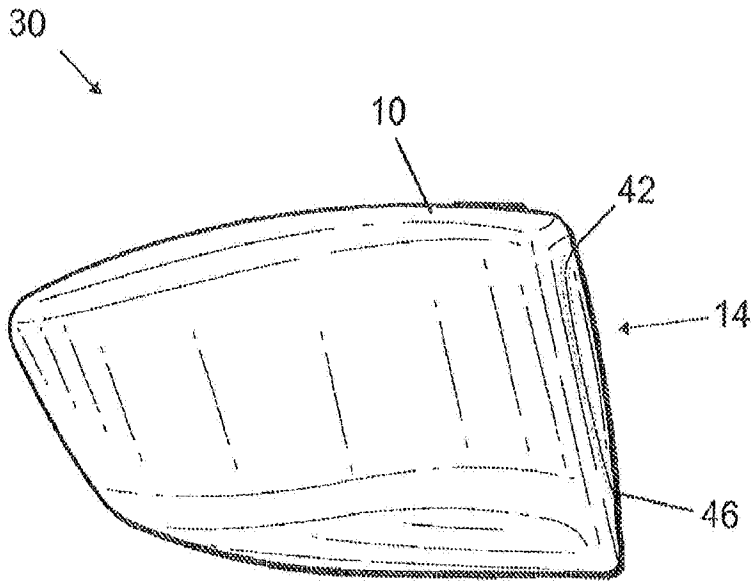


FIG. 5

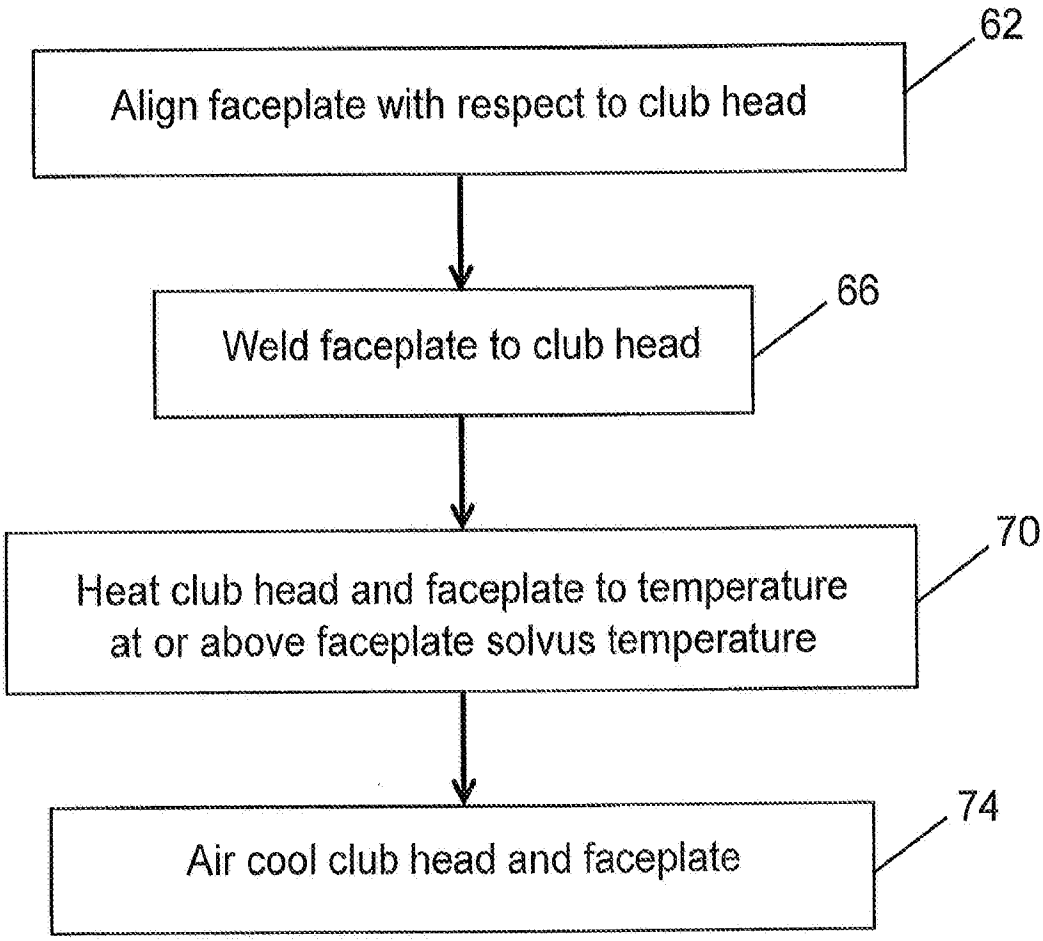

Align faceplate with respect to club head
62
Weld faceplate to club head
66
Heat club head and faceplate to temperature at or above faceplate solvus temperature
70
Air cool club head and faceplate
74

FIG. 6

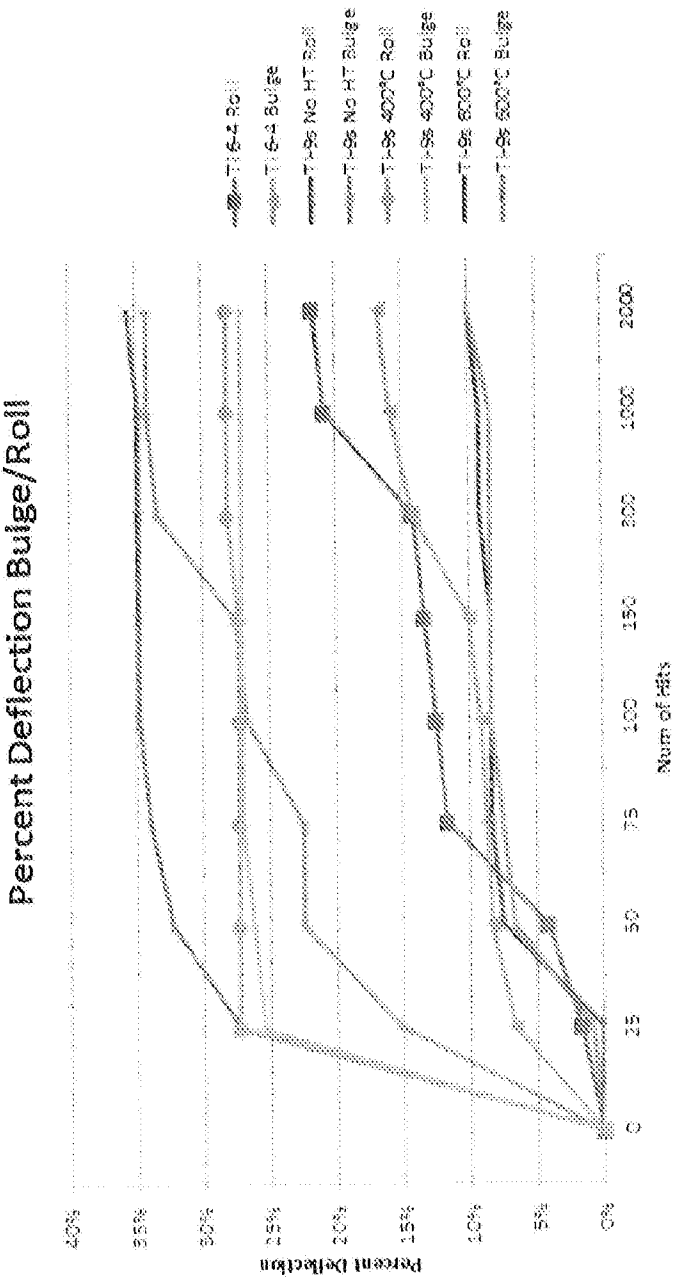

Percent Deflection Bulge/Roll
Percent Deflection
40%
35%
30%
25%
20%
15%
10%
5%
0%
0
25
50
75
100
150
200
1000
2000
Num of Hits
Ti-6-4 Roll
Ti-6-4 Bulge
Ti-6s No HT Roll
Ti-6s No HT Bulge
Ti-6s 400°C Roll
Ti-6s 400°C Bulge
Ti-6s 600°C Roll
Ti-6s 600°C Bulge

FIG. 7

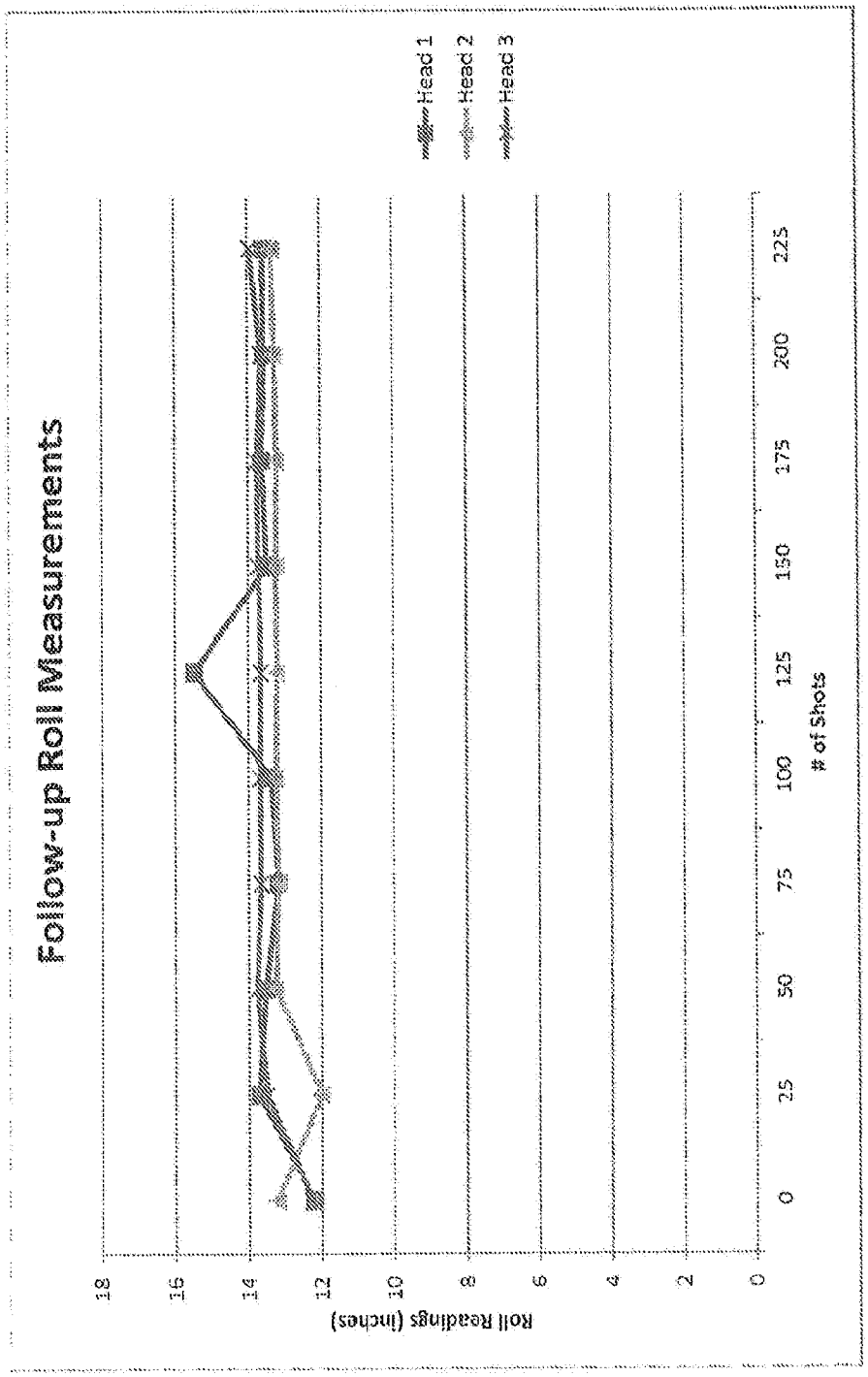

Follow-up Roll Measurements
Head 1
Head 2
Head 3
Roll Readings (Inches)
18
16
14
12
10
8
6
4
2
0
0
25
50
75
100
125
150
175
200
225
# of Shots

FIG. 8

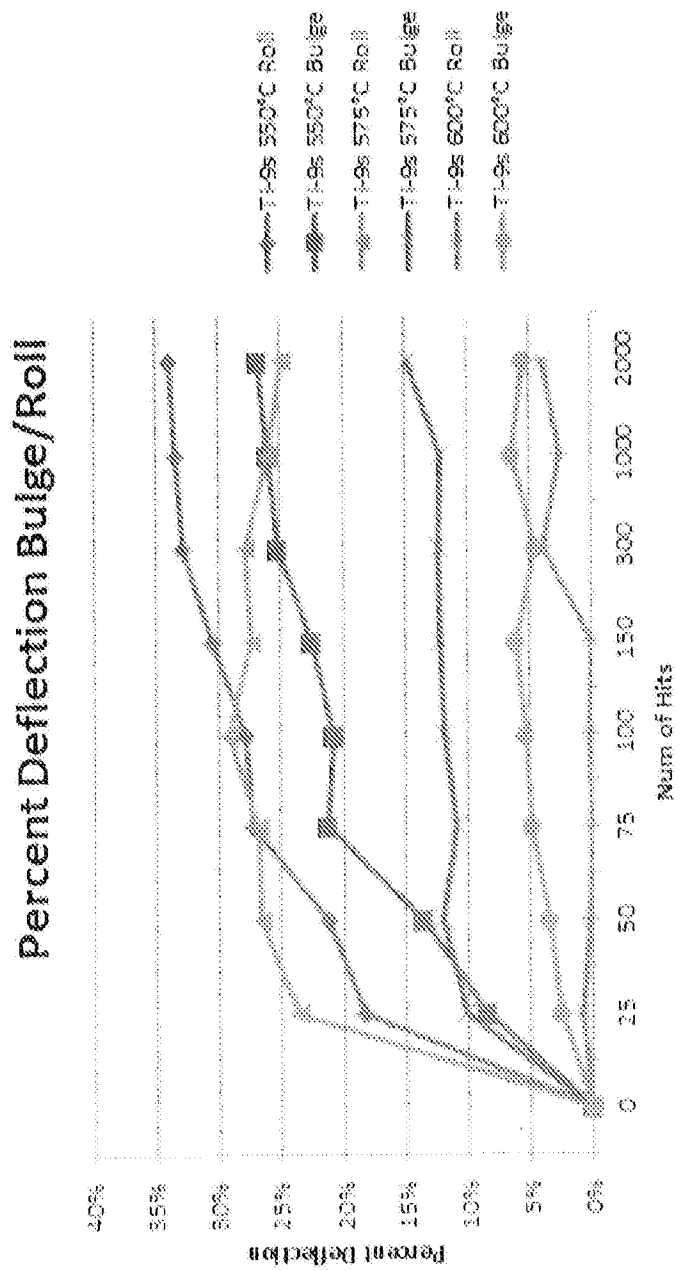

Percent Deflection Bulge/Roll
Percent Deflection
40%
35%
30%
25%
20%
15%
10%
5%
0%
0
25
50
75
100
150
300
1000
2000
Num of Hits
T-9s 550°C Roll
T-9s 550°C Bulge
T-9s 575°C Roll
T-9s 575°C Bulge
T-9s 600°C Roll
T-9s 600°C Bulge

FIG. 9

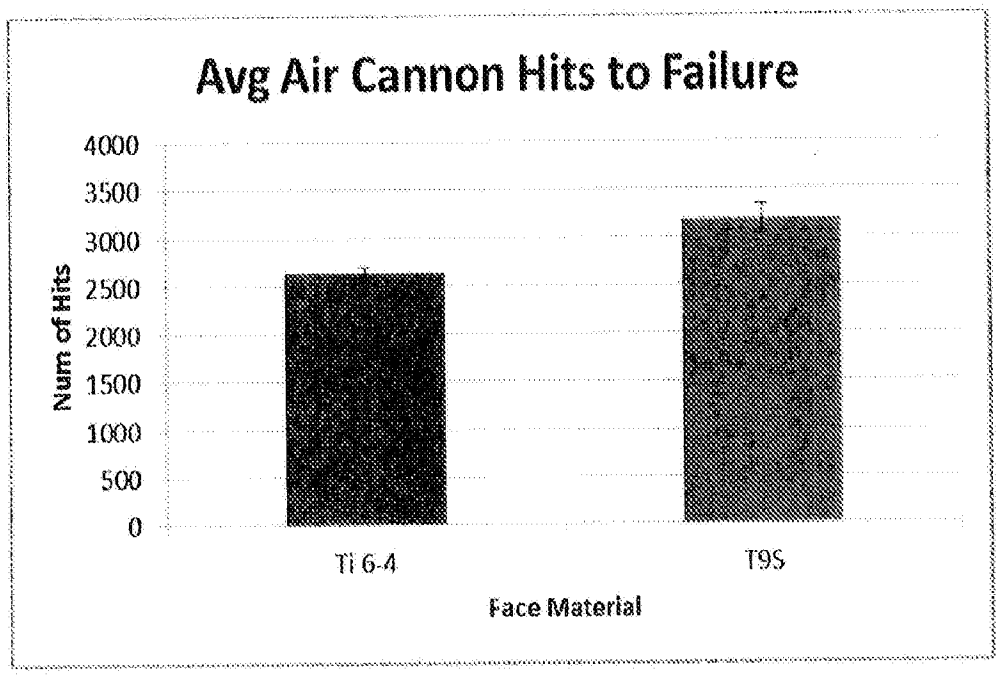

Avg Air Cannon Hits to Failure
Num of Hits
4000
3500
3000
2500
2000
1500
1000
500
0
Ti 6-4
T9S
Face Material

FIG. 10

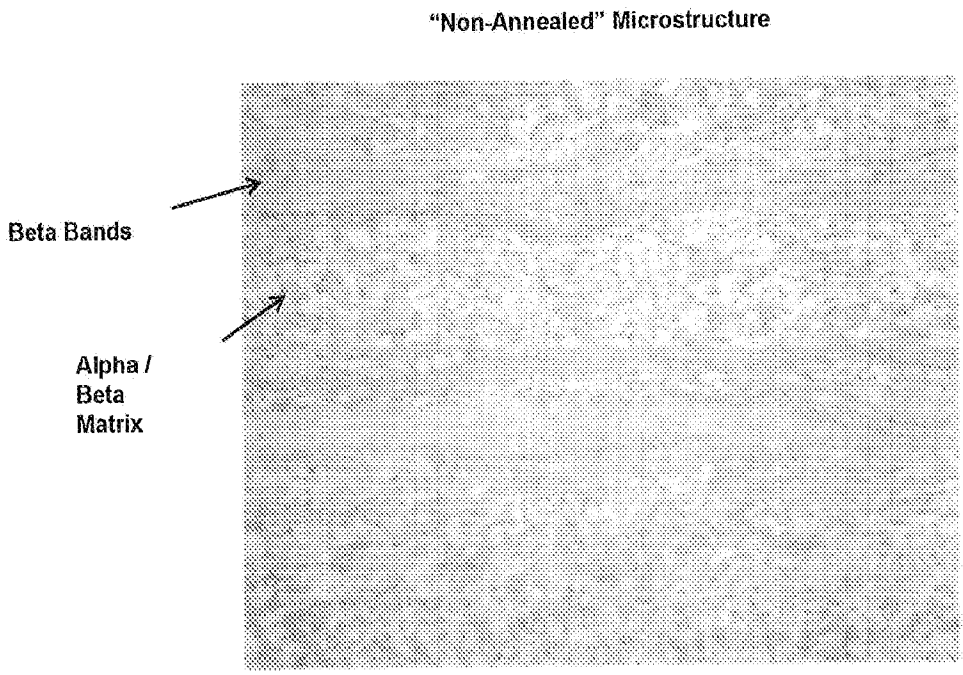


FIG. 11A

"Annealed" Microstructure

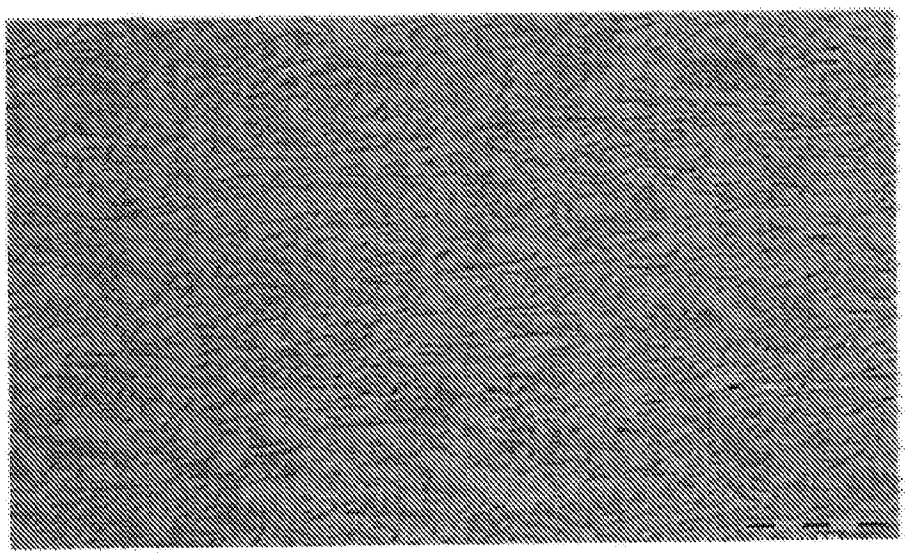


FIG. 11B

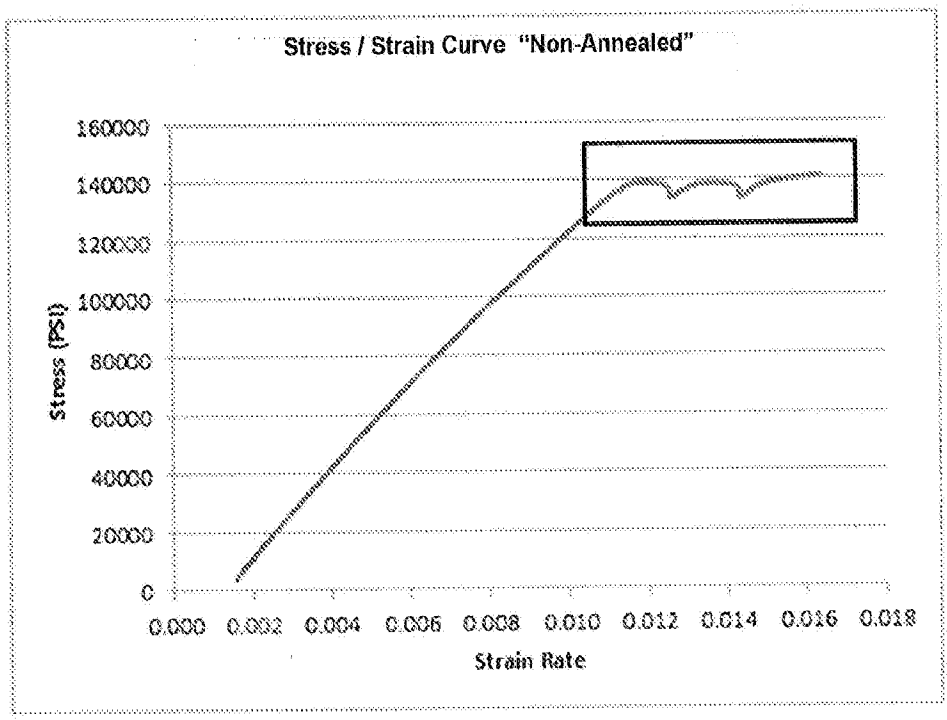

Stress / Strain Curve "Non-Annealed"
160000
140000
120000
100000
80000
60000
40000
20000
0
Stress (PSI)
0.000
0.002
0.004
0.006
0.008
0.010
0.012
0.014
0.016
0.018
Strain Rate

FIG. 11C

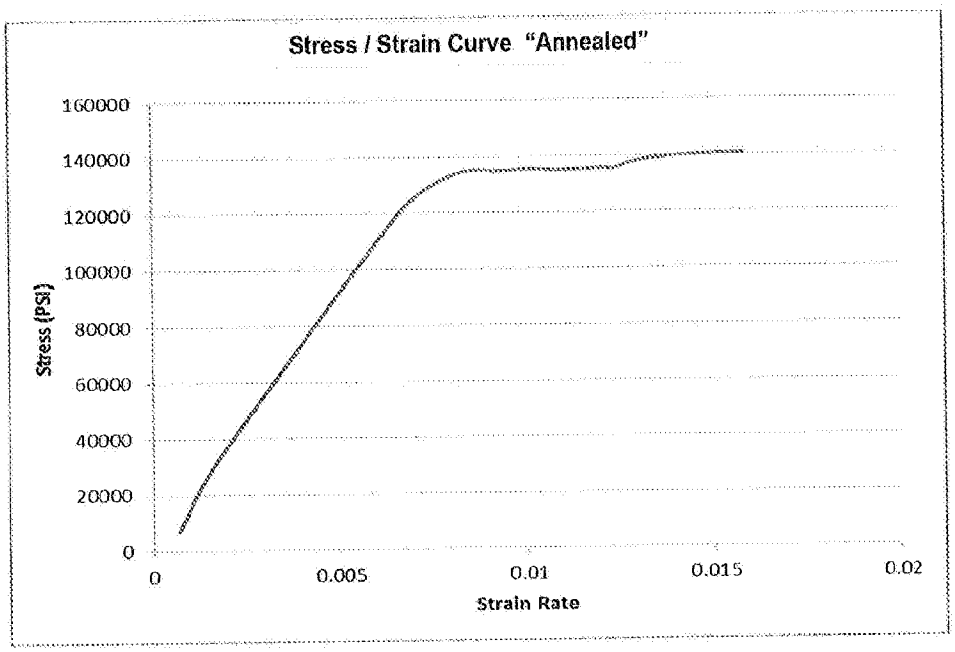

Stress / Strain Curve "Annealed"
160000
140000
120000
100000
80000
60000
40000
20000
0
Stress (PSI)
0
0.005
0.01
0.015
0.02
Strain Rate

FIG. 11D

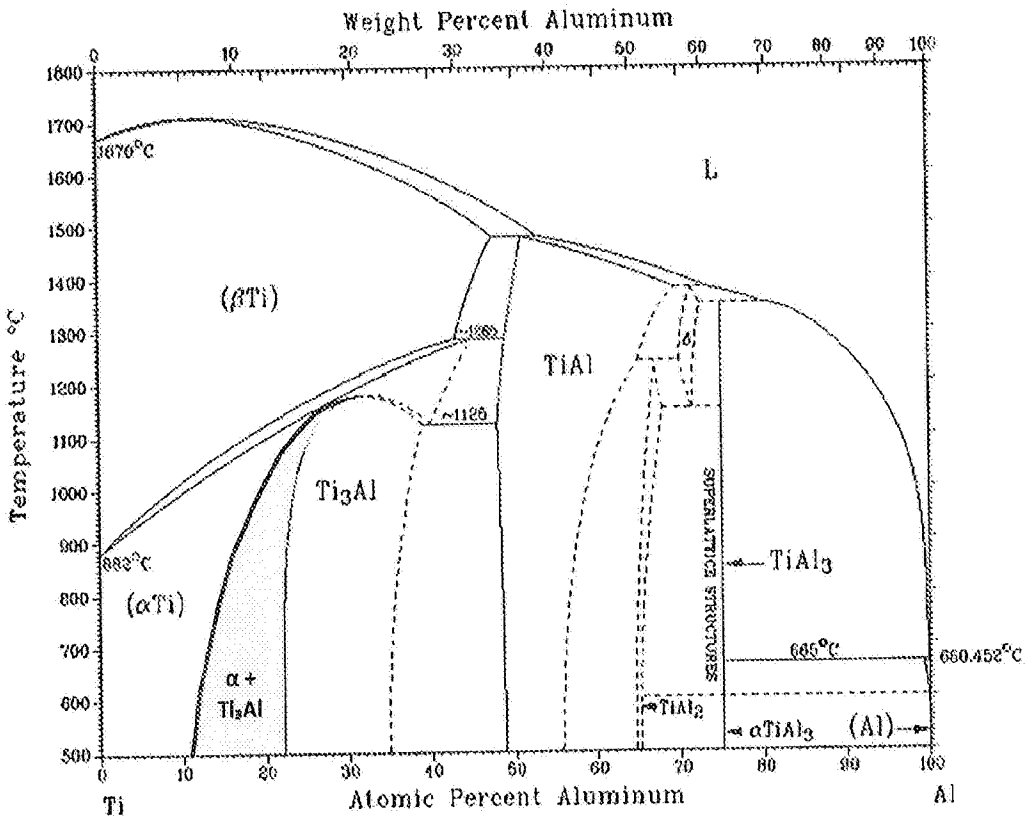

Weight Percent Aluminum
Temperature °C
Atomic Percent Aluminum
Ti
Al
1676°C
L
(βTi)
TiAl
Ti3Al
(αTi)
α +
Ti3Al
TiAl3
665°C
660.452°C
TiAl2
αTiAl3
(Al)
SUPERLATTICE STRUCTURES

FIG. 12

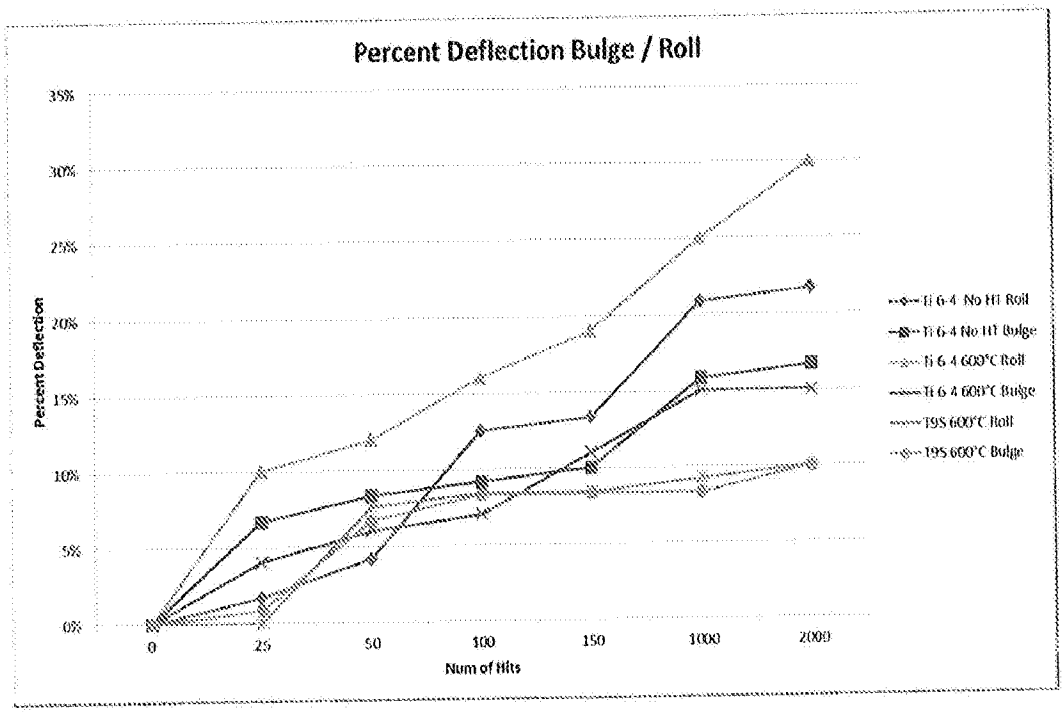
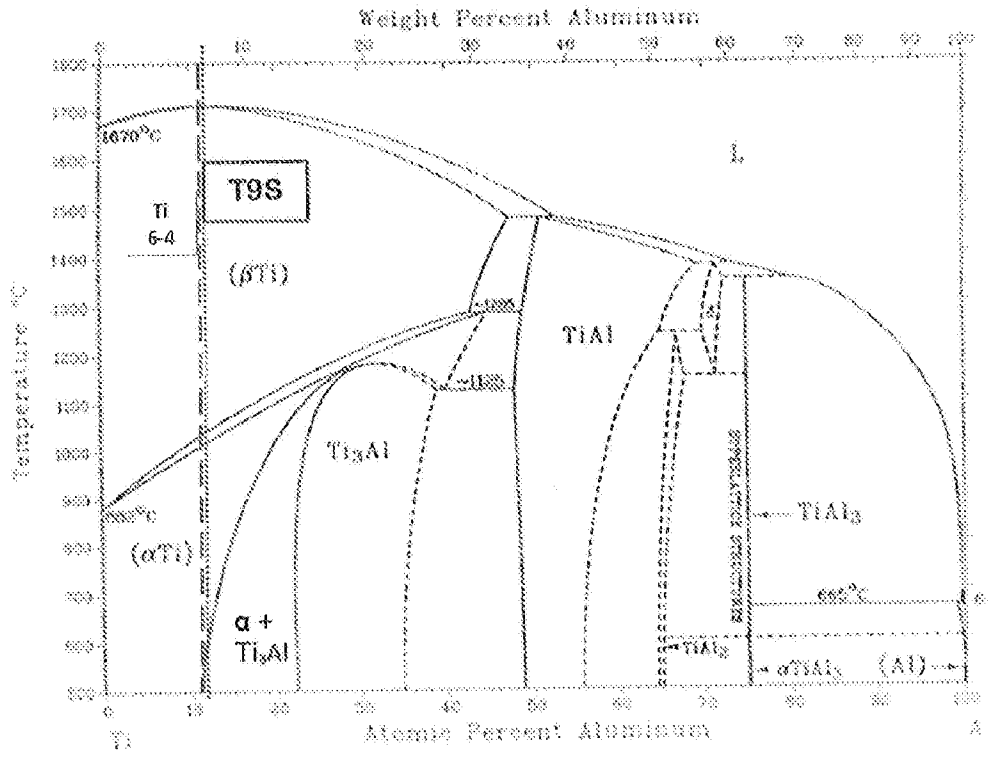

Percent Deflection Bulge / Roll
35%
30%
25%
20%
15%
10%
5%
0%
Percent Deflection
0
25
50
100
150
1000
2000
Num of Hits
Ti 6-4 No HT Roll
Ti 6-4 No HT Bulge
Ti 6-4 600°C Roll
Ti 6-4 600°C Bulge
T9S 600°C Roll
T9S 600°C Bulge

FIG. 13

Ti-Al Phase Diagram



From ASM Handbook, Volume 3, Alloy Phase Diagrams

FIG. 14

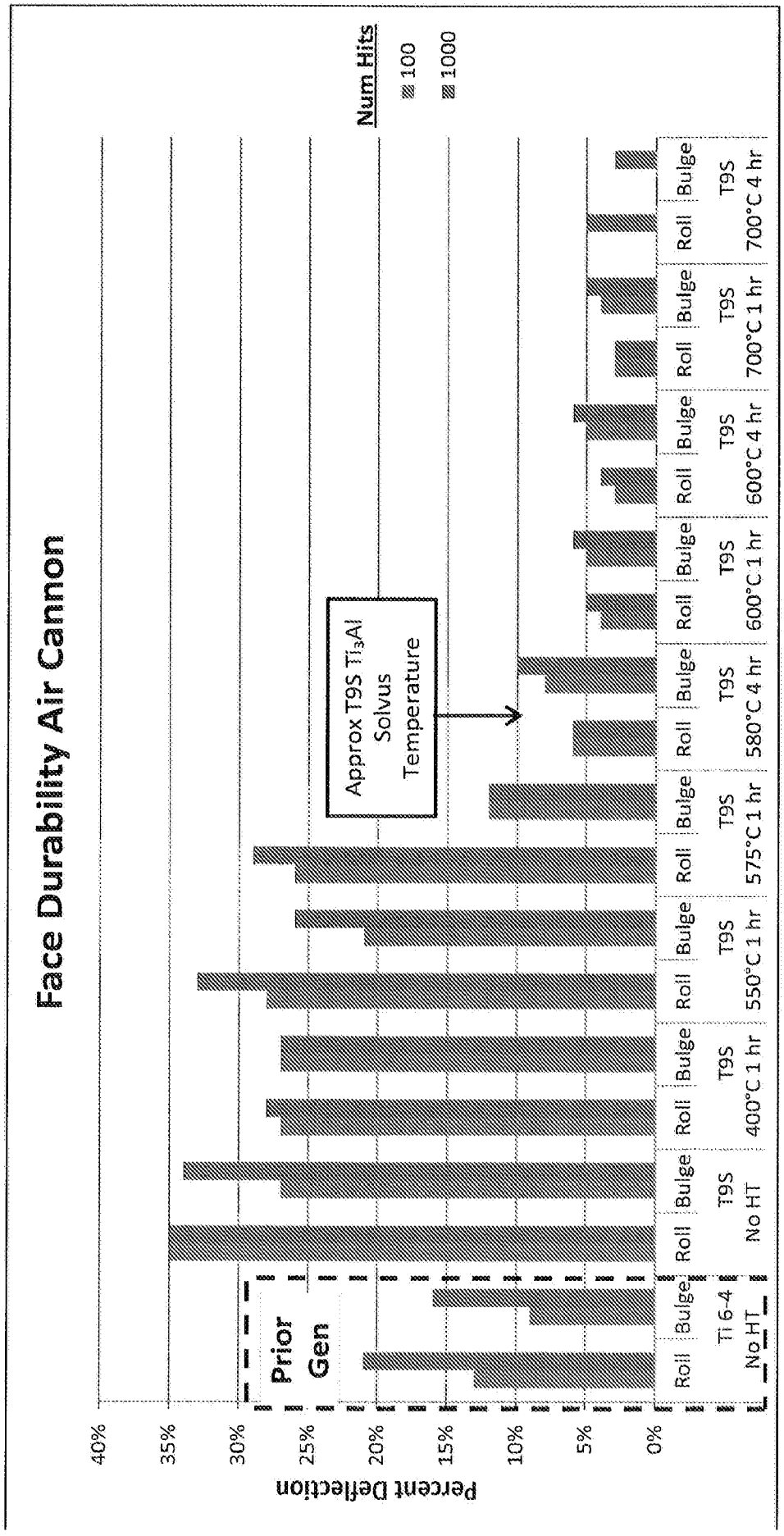

Face Durability Air Cannon
Num Hits
100
1000
Approx T9S Ti_3Al Solvus Temperature
Prior Gen
Percent Deflection
40%
35%
30%
25%
20%
15%
10%
5%
0%
Ti 6-4 No HT
T9S No HT
Roll Bulge Roll Bulge Roll Bulge Roll Bulge Roll Bulge Roll Bulge Roll Bulge Roll Bulge Roll Bulge Roll Bulge
T9S 400°C 1 hr
T9S 550°C 1 hr
T9S 575°C 1 hr
T9S 580°C 4 hr
T9S 600°C 1 hr
T9S 600°C 4 hr
T9S 700°C 1 hr
T9S 700°C 4 hr

FIG. 15

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 16/18287

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - A63B 53/04, C22F 1/18, C22C 14/00 (2016.01)
CPC - C22F 1/183, A63B 53/00, A63B 53/04
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC (8): A63B53/00, A63B53/04, B21D31/00, B23P17/00, A61L27/00, A61L27/02, A61L27/04, A61L27/06, B62D29/00, B64C1/00, C22C14/00, C22F1/00, C22F1/16, C22F1/18, F16B19/00, F16B19/04, F16B33/00, F16B37/00, F16B39/00, F16B43/00 (2016.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
CPC: A63B49/00, A63B53/00, A63B53/04, A63B53/0466, A63B2053/* A63B2209/00, A63B2209/02, A63B2209/023, A61L15/00, A61L27/00, A61L27/02, A61L27/04, A61L27/06, B62D21/00, B62D29/00, C22C1/*, C22F1/*, Y10T29/* USPC: 146/*, 420/* 29/*, 473/*

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Patbase, Google (Web, Images, Patents, Scholar)
Golf, club, head, alloy, insert, weld, forge, heat, time, maintain, Al, Ti, weight, percent, percentage, alpha, beta, alpha-beta, solvus, gas, inert, cool, V, O, oxygen, vanadium, silicon, range, increase, anneal,

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2003/0064825 A1 (Sano).03 April 2003 (03.04.2003) entire document, especially Title; Abstract; fig. 1-3, para [0022]-[0028].	1-30
A	US 2003/0008726 A1 (Sano) 09 January 2003 (09.01.2003) entire document, especially figs. 1-3, para [0013], [0019]-[0020], [0033]-[0036].	1-30
A	US 6,723,279 B1 (Withers et al.) 20 April 2004 (20.04.2004) entire document, especially Title; Abstract, col 26, ln 33-55.	1-30
A	US 2010/0178996 A1 (Chao) 15 July 2010 (15.07.2010) entire document, especially figs. 1-3; Title; Abstract, para [0056]).	1-30
A	US 2006/0062685 A1 (Takahashi) 23 March 2006 (23.03.2006) entire document, especially Title; Abstract, para [0010], [0012], [0016], [0026], [0063].	1-30
A	US 2004/0147343 A1 (Billings et al.) 29 July 2004 (29.07.2004) entire document.	1-30
A	US 2010/0154196 A1 (HIRANO) 24 June 2010 (24.06.2010) entire document.	1-30
A	'Titanium alloys in total joint replacement - a materials science perspective' (Long et al.) - Biomaterials 19 (1998) pgs1621-1639 entire document.	1-30
A	US 2012/0076611 A1 (Bryan) 29 March 2012 (29.03.2012) entire document.	1-30

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 April 2016	02 MAY 2016
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774