US012390695B2

(12) United States Patent
Watanabe

(10) Patent No.: US 12,390,695 B2
(45) Date of Patent: *Aug. 19, 2025

(54) **MULTI-PIECE SOLID GOLF BALL**

(71) Applicant: **BRIDGESTONE SPORTS CO., LTD.**, Tokyo (JP)

(72) Inventor: **Hideo Watanabe**, Saitamaken (JP)

(73) Assignee: **BRIDGESTONE SPORTS CO., LTD.**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **18/490,406**

(22) Filed: **Oct. 19, 2023**

(65) **Prior Publication Data**

US 2024/0149117 A1 May 9, 2024

(30) **Foreign Application Priority Data**

Nov. 8, 2022 (JP) 2022-179044

(51) **Int. Cl.**
A63B 37/06 (2006.01)
A63B 37/00 (2006.01)

(52) **U.S. Cl.**
CPC ***A63B 37/0075*** (2013.01); ***A63B 37/00215*** (2020.08); ***A63B 37/0084*** (2013.01); ***A63B 37/0087*** (2013.01); ***A63B 37/00922*** (2020.08)

(58) **Field of Classification Search**
CPC A63B 37/0075; A63B 37/0084; A63B 37/0087; A63B 37/00922; A63B 37/0063; A63B 37/0068
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2008/0176676 A1* 7/2008 Watanabe A63B 37/0062 473/376
2011/0250987 A1 10/2011 Umezawa et al.
2011/0250988 A1 10/2011 Umezawa et al.
2011/0250989 A1 10/2011 Umezawa et al.
2011/0287862 A1 11/2011 Higuchi et al.
(Continued)

FOREIGN PATENT DOCUMENTS

JP 2011-218160 A 11/2011
JP 2011-218161 A 11/2011
(Continued)

Primary Examiner — Raeann Gorden
(74) *Attorney, Agent, or Firm* — Sughrue Mion, PLLC

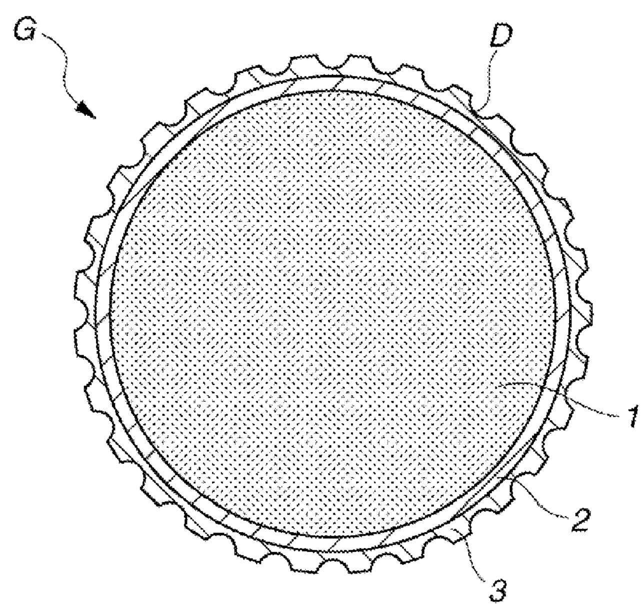
(57) **ABSTRACT**

Provided is a golf ball including a core, an intermediate layer, and a cover. A relationship between surface hardness of an intermediate layer-encased sphere and surface hardness of the ball satisfies a predetermined relational expression. With an initial velocity of the ball and a deflection under a predetermined load applied to the ball optimized, and letting a value of (initial velocity of core×weight of core) be Ciw, a value of [(initial velocity of intermediate layer-encased sphere−initial velocity of core)×(weight of intermediate layer-encased sphere−weight of core)] be Miw, and a value of [(initial velocity of ball−initial velocity of intermediate layer-encased sphere)×(weight of ball−weight of intermediate layer-encased sphere)] be CViw, the following expression is satisfied:

$$2500 \leq Ciw+Miw+CViw \leq 2650.$$

A volume occupancy ratio of dimples is set to a predetermined range.

8 Claims, 6 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2011/0287863	A1	11/2011	Higuchi et al.	
2011/0287864	A1	11/2011	Umezawa et al.	
2011/0287867	A1	11/2011	Higuchi et al.	
2011/0287868	A1	11/2011	Umezawa et al.	
2011/0287869	A1	11/2011	Umezawa et al.	
2012/0277020	A1	11/2012	Higuchi et al.	
2013/0095955	A1	4/2013	Higuchi et al.	
2013/0172106	A1	7/2013	Shinohara	
2013/0172107	A1	7/2013	Higuchi et al.	
2013/0172108	A1	7/2013	Higuchi et al.	
2024/0226666	A9*	7/2024	Watanabe	A63B 37/0075
2024/0299811	A1*	9/2024	Watanabe	A63B 37/0076

FOREIGN PATENT DOCUMENTS

JP	2011-218162	A	11/2011
JP	2011-240122	A	12/2011
JP	2011-240123	A	12/2011
JP	2011-240124	A	12/2011
JP	2011-240125	A	12/2011
JP	2011-240126	A	12/2011
JP	2011-240127	A	12/2011
JP	2012-228470	A	11/2012
JP	2013-138839	A	7/2013
JP	2013-138840	A	7/2013
JP	2013-138857	A	7/2013
JP	2014-69045	A	4/2014

* cited by examiner

FIG.1

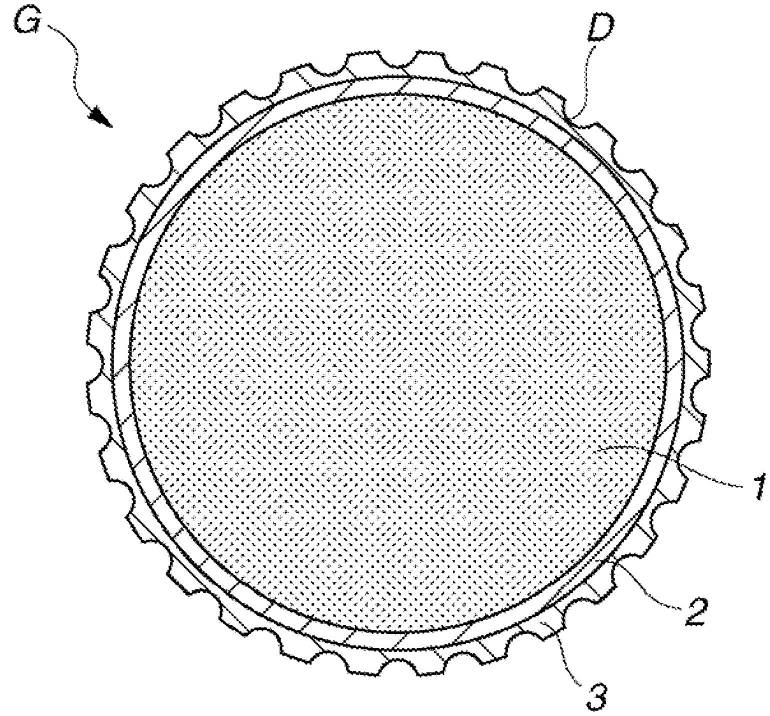


FIG.2

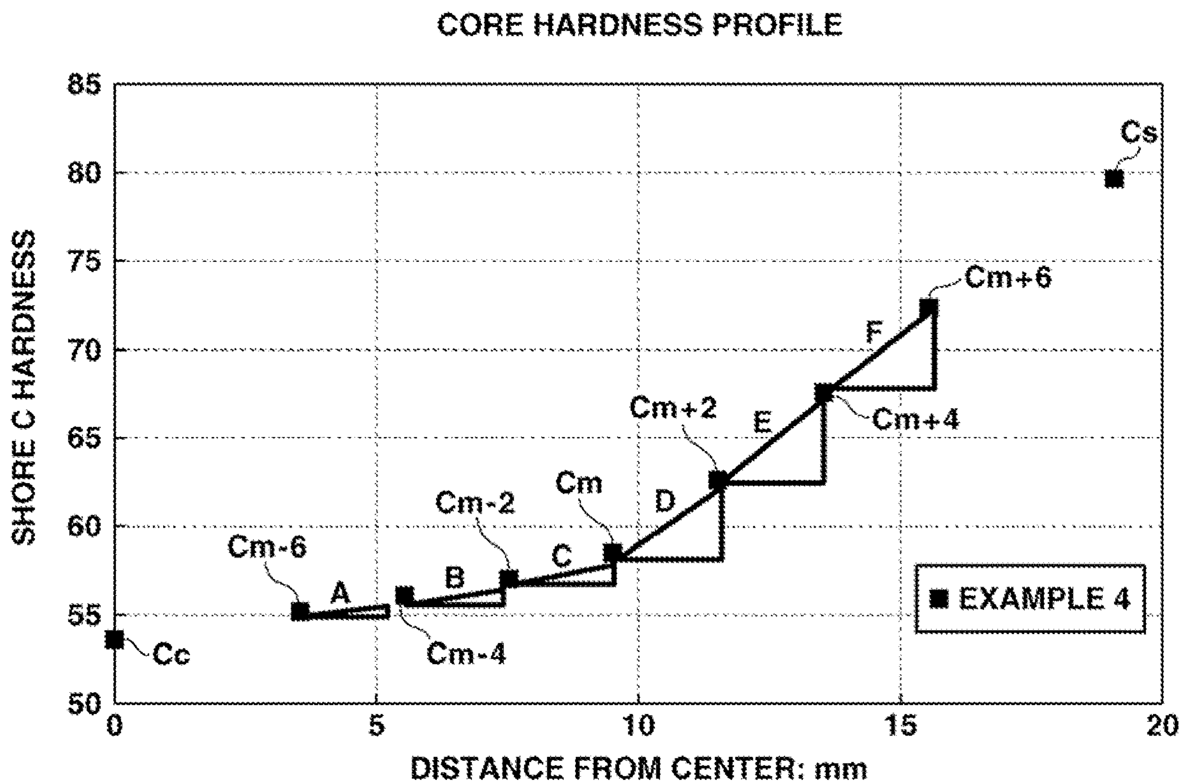

CORE HARDNESS PROFILE
SHORE C HARDNESS
DISTANCE FROM CENTER: mm
85
80
75
70
65
60
55
50
0
5
10
15
20
Cs
Cm+6
F
Cm+4
E
Cm+2
D
Cm
C
Cm-2
B
Cm-4
A
Cm-6
Cc
EXAMPLE 4

FIG.3

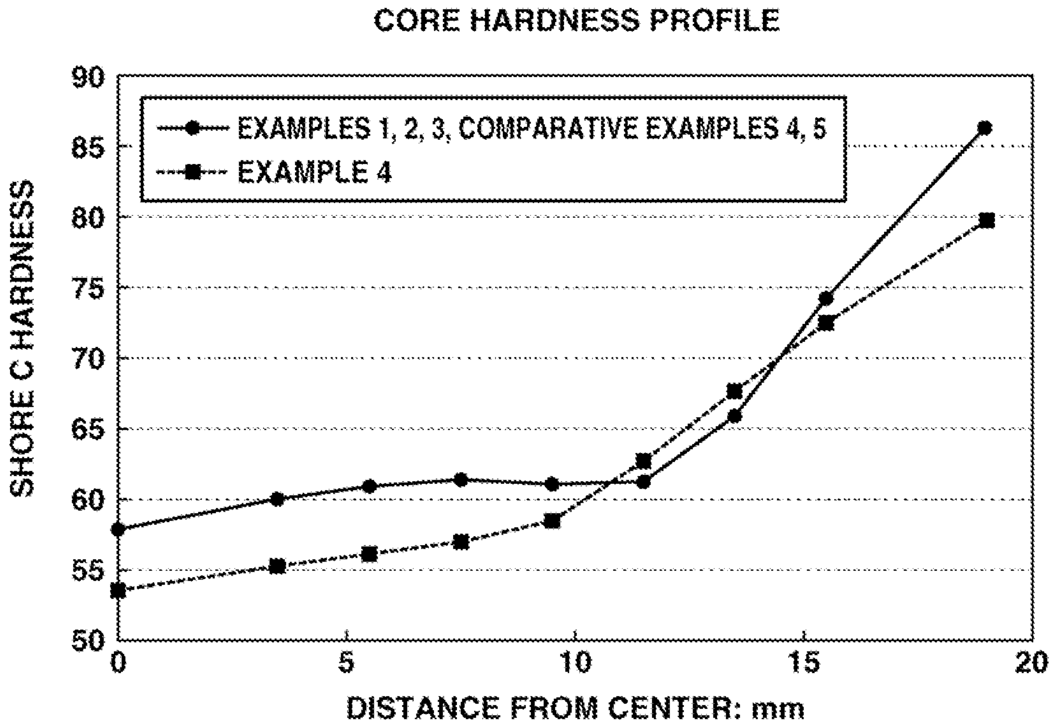

CORE HARDNESS PROFILE
SHORE C HARDNESS
DISTANCE FROM CENTER: mm
EXAMPLES 1, 2, 3, COMPARATIVE EXAMPLES 4, 5
EXAMPLE 4
90
85
80
75
70
65
60
55
50
0
5
10
15
20

FIG.4

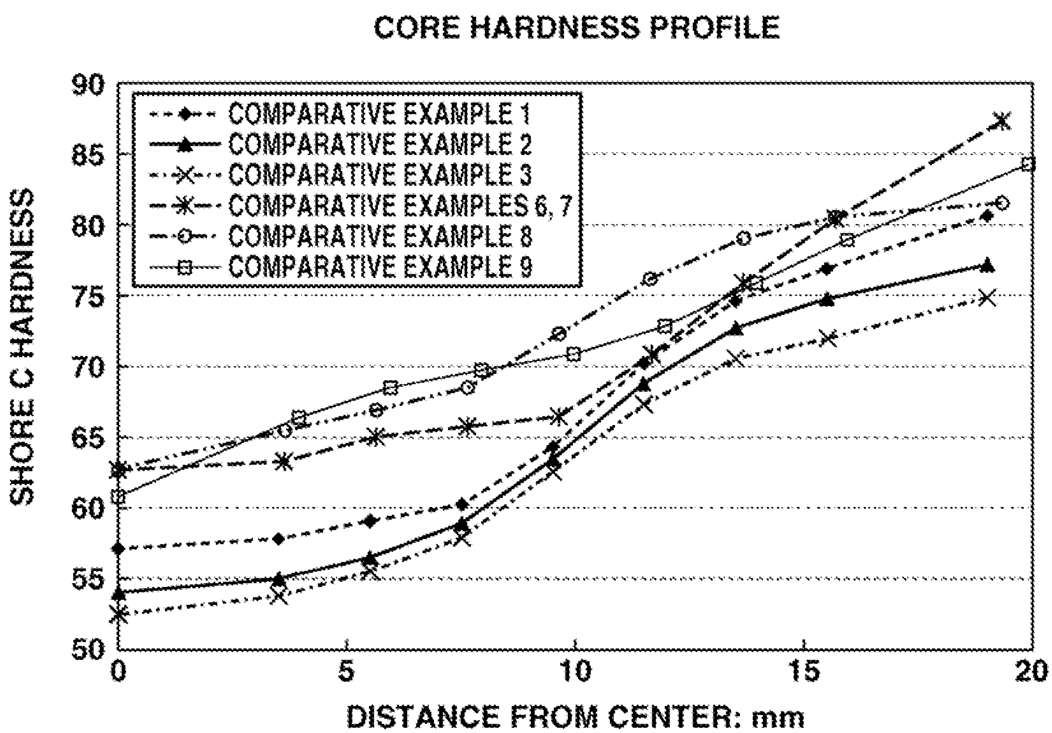

CORE HARDNESS PROFILE
SHORE C HARDNESS
DISTANCE FROM CENTER: mm
COMPARATIVE EXAMPLE 1
COMPARATIVE EXAMPLE 2
COMPARATIVE EXAMPLE 3
COMPARATIVE EXAMPLES 6, 7
COMPARATIVE EXAMPLE 8
COMPARATIVE EXAMPLE 9
90
85
80
75
70
65
60
55
50
0
5
10
15
20

FIG.5

Ciw+Miw+CViw

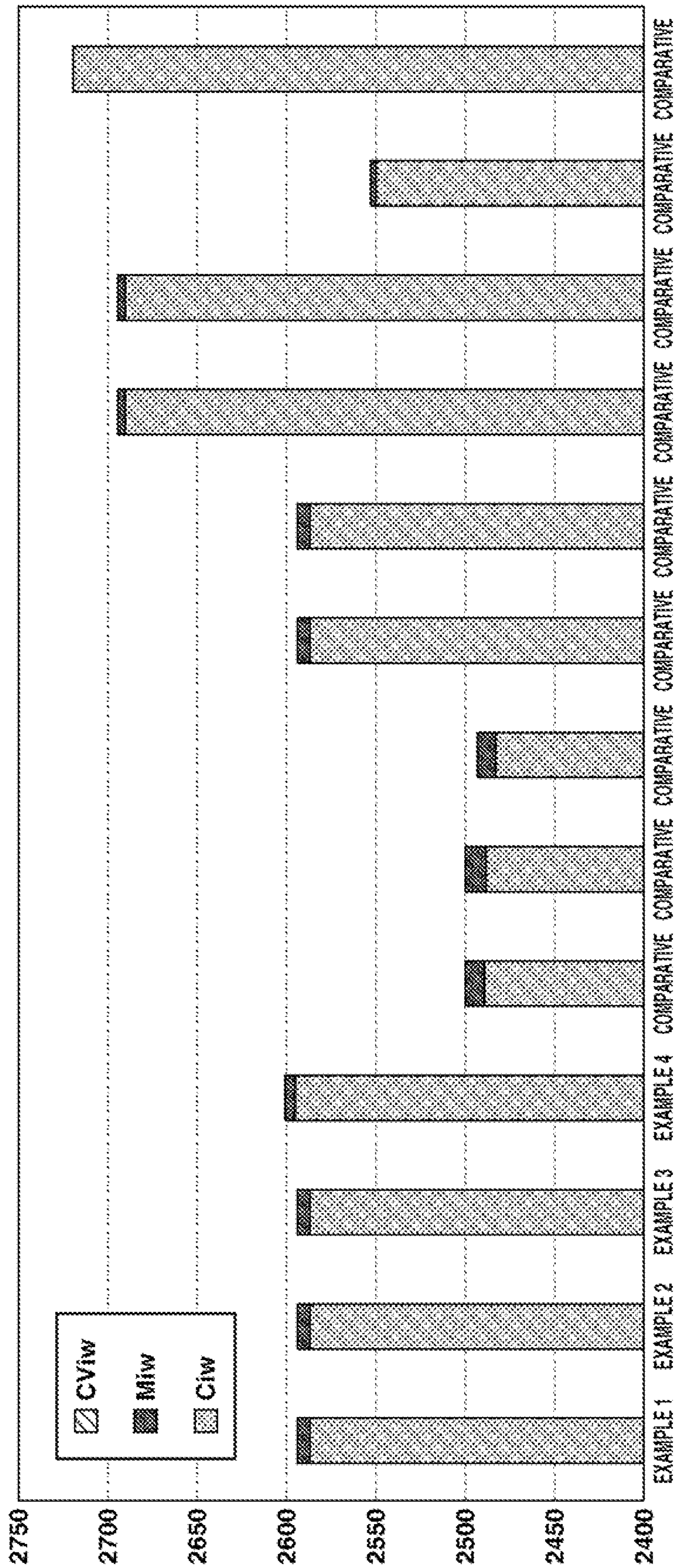


FIG.6A

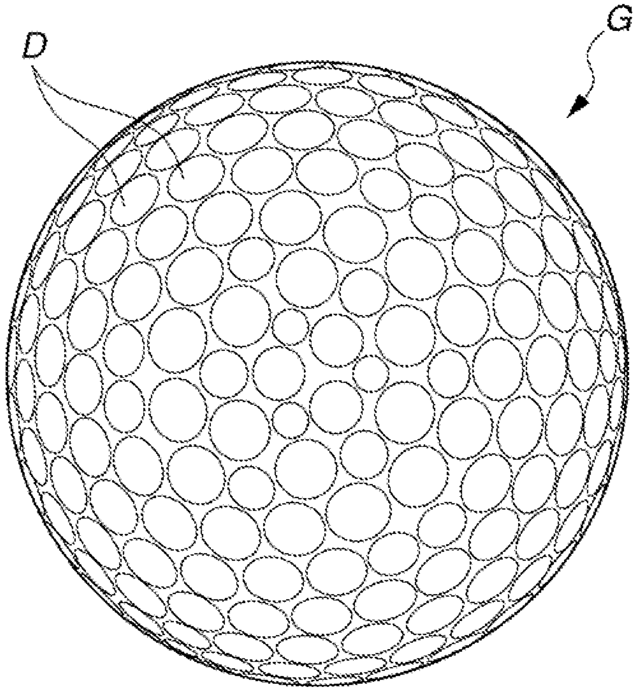


FIG.6B

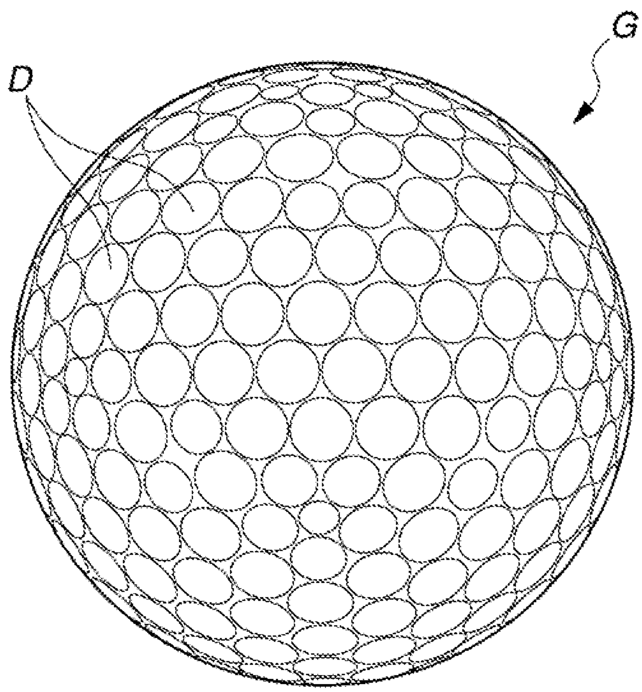


FIG.7A

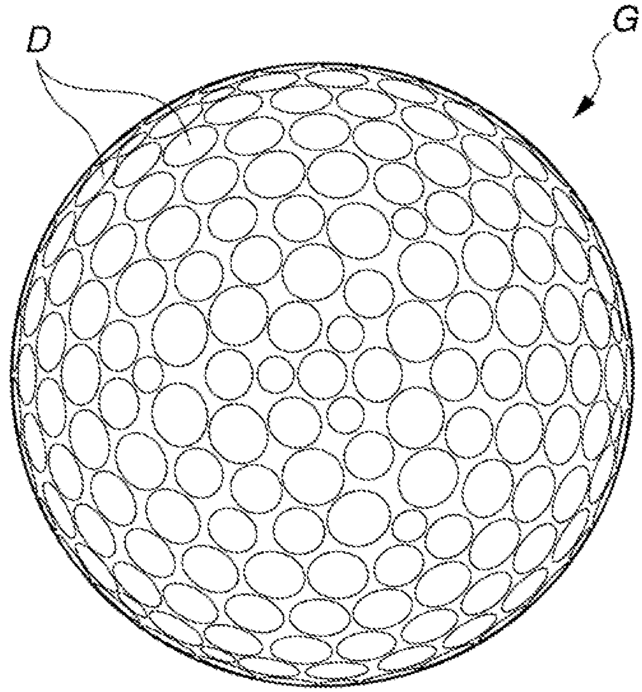
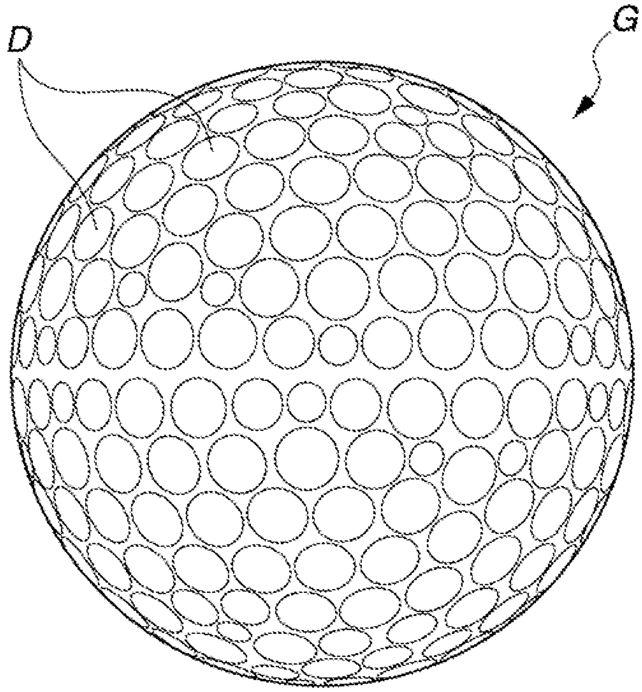


FIG.7B



MULTI-PIECE SOLID GOLF BALL

CROSS-REFERENCE TO RELATED APPLICATIONS

This non-provisional application claims priority under 35 U.S.C. § 119(a) on Patent Application No. 2022-179044 filed in Japan on Nov. 8, 2022, the entire contents of which are hereby incorporated by reference.

TECHNICAL FIELD

The present invention relates to a multi-piece solid golf ball including a core, an intermediate layer, and a cover, wherein a large number of dimples are formed on an outer surface of the cover.

BACKGROUND ART

In March 2022, manufacturers of golf balls were notified by the Royal and Ancient Golf Club of St Andrews (hereinafter, R&A) and the United States Golf Association (herein after, USGA) that they would start research to suppress the distance by long hitters by changing test conditions for the Overall Distance Standard (hereinafter, ODS) of golf balls in the future. For this reason, it is preferable to provide a golf ball that does not simply reduce distance, but while making the distance for reducing the distance on shots with a driver by long hitters larger, by making the distance for reducing the distance on shots with a driver and an iron by average hitters smaller, reduces the influence on play other than reducing the distance on shots with a driver by long hitters. In addition, due to the above changes, it is desirable to design the ball so that its spin characteristics in the short game have a similar performance to those of the ball used in the current tour so that a sense of discomfort does not occur for professionals or advanced players when using the golf ball with the reduced distance.

In the past, some golf balls in which an initial velocity of the ball is restricted to not more than 76.5 m/s have been proposed. Examples of such technical documents include the following Patent Documents 1 to 5.

However, each of the proposed golf balls is a practice ball for a driving range that is simply designed so as not to have a larger distance than a game ball. Therefore, the golf ball is not designed such that while reducing the distance on shots with a driver (W#1) by long hitters, the distance for reducing the distance of average hitters is made smaller than the distance for reducing the distance by long hitters.

Further, Patent Documents 6 to 14 listed below each disclose a golf ball in which, as for dimples formed on the ball surface, a sum of the volumes of the individual dimples, formed below the flat plane circumscribed by the edge of a dimple, to a ball spherical volume on the assumption that the ball has no dimples, that is, a dimple volume occupancy ratio VR, is specified within a predetermined value, whereby a superior distance can be obtained in the low HS range while reducing the distance in the high head speed (HS) range.

However, with the golf balls proposed above, the distance on shots with the driver (W#1) by long hitters is reduced, and a desired distance on shots with an iron by both long hitters and average hitters is not attainable. Therefore, it is desirable to prevent the distance in shots with the iron from being reduced for both long hitters and average hitters as much as possible.

CITATION LIST

Patent Document 1: JP-A 2012-228470
Patent Document 2: JP-A 2014-069045

Patent Document 3: JP-A 2013-138857
Patent Document 4: JP-A 2013-138839
Patent Document 5: JP-A 2013-138840
Patent Document 6: JP-A 2011-218160
Patent Document 7: JP-A 2011-218161
Patent Document 8: JP-A 2011-218162
Patent Document 9: JP-A 2011-240122
Patent Document 10: JP-A 2011-240123
Patent Document 11: JP-A 2011-240124
Patent Document 12: JP-A 2011-240125
Patent Document 13: JP-A 2011-240126
Patent Document 14: JP-A 2011-240127

SUMMARY OF THE INVENTION

The present invention has been made in view of the above circumstances, and to address the possibility of there being a change to the rules in the future to suppress the distance by long hitters by changing the test conditions for the ODS of golf balls, an object of the present invention is to provide a golf ball that is intended to reduce the influence on play other than reducing the distance on shots with a driver by long hitters, instead of simply reducing distance, while making the distance for reducing the distance on shots with a driver by long hitters larger, by making the distance for reducing the distance on shots with a driver (W#1) by average hitters and with an iron by both long hitters and average hitters smaller.

As a result of intensive studies to achieve the above object, the present inventor has found that in a multi-piece solid golf ball including a core, an intermediate layer, and a cover, in which a large number of dimples are formed on an outer surface of the cover, a relationship between a surface hardness of an intermediate layer-encased sphere and a surface hardness of the ball satisfies the following condition:

$$\text{(surface hardness of ball)} < \text{(surface hardness of intermediate layer-encased sphere)}$$

(where the surface hardnesses mean Shore C hardnesses).

Further, the present inventor has found that when an initial velocity of the ball is set to 76.5 to 77.724 m/s and a deflection set to at least 2.7 mm when the ball is compressed under a final load of 1,275 N (130 kgf) from an initial load of 98 N (10 kgf), and a value of (initial velocity of core×weight of core) is denoted by Ciw, a value of [(initial velocity of intermediate layer-encased sphere−initial velocity of core)×(weight of intermediate layer-encased sphere−weight of core)] is denoted by Miw, and a value of [(initial velocity of ball−initial velocity of intermediate layer-encased sphere)×(weight of ball−weight of intermediate layer-encased sphere)] is denoted by CViw, the following condition is satisfied:

$$2500 \leq Ciw + Miw + CViw \leq 2{,}650.$$

Further, the present inventor has found that by setting a volume occupancy ratio VR of the dimples within a range of 0.75 to 0.89%, in a golf ball conforming to the rules for suppressing the distance by long hitters, even if a distance for reducing a distance on shots with a driver by long hitters is made larger, making the distance for reducing each distance on shots with a driver (W#1) by average hitters and on shots with an iron by both long hitters and average hitters as small as possible reduces an influence on play other than reducing the distance on shots with a driver by long hitters, and has completed the present invention. In addition, the golf ball of the present invention has a similar performance to the ball used in the current tour with respect to its spin characteristics in the short game so that a sense of discomfort does not occur for professionals or advanced players when using the golf ball.

The above "long hitters" mean users whose head speed on shots with a driver (W#1) is at least about 50 m/s, and the above "average hitters" mean users whose head speed on shots with a driver (W#1) is less than about 45 m/s.

Accordingly, the present invention provides a multi-piece solid golf ball including a core, an intermediate layer, and a cover, wherein a large number of dimples are formed on an outer surface of the cover, and a relationship between a surface hardness of an intermediate layer-encased sphere and a surface hardness of the ball satisfies the following condition: (surface hardness of ball)<(surface hardness of intermediate layer-encased sphere) (where the surface hardnesses mean Shore C hardnesses).

Further characteristics of the multi-piece solid golf ball are that when an initial velocity of the ball is from 76.5 to 77.724 m/s and a deflection is at least 2.7 mm when the ball is compressed under a final load of 1,275 N (130 kgf) from an initial load of 98 N (10 kgf), a value of (initial velocity of core×weight of core) is denoted by Ciw, a value of [(initial velocity of intermediate layer-encased sphere−initial velocity of core)×(weight of intermediate layer-encased sphere−weight of core)] is denoted by Miw, and a value of [(initial velocity of ball−initial velocity of intermediate layer-encased sphere)×(weight of ball−weight of intermediate layer-encased sphere)] is denoted by CViw, the following condition is satisfied:

$$2{,}500 \leq Ciw+Miw+CViw \leq 2{,}650, \text{ and}$$

a volume occupancy ratio VR of the dimples are 0.75 to 0.89%.

In a preferred embodiment of the multi-piece golf ball according to the invention, when an initial velocity of the core is denoted by Vc (m/s), and a deflection is denoted by C (mm) when the core is compressed under a final load of 1,275 N (130 kgf) from an initial load of 98 N (10 kgf), the following condition is satisfied:

$$15 \leq Vc/C \leq 25.$$

In another preferred embodiment of the inventive golf ball, a relationship between a surface hardness of the core and the surface hardness of the intermediate layer-encased sphere satisfies the following condition:

$$(\text{surface hardness of intermediate layer-coated sphere}) \geq (\text{surface hardness of core})$$

(where the hardnesses mean Shore C hardnesses).

In yet another preferred embodiment, when each sphere of the core, the intermediate layer-encased sphere, and the ball is compressed under a final load of 1,275 N (130 kgf) from an initial load of 98 N (10 kgf) and the deflections (mm) are denoted by C (mm), M (mm), and B (mm) respectively, the following two conditions are satisfied:

$$1.00 \leq C-B \leq 1.50$$

$$0.65 \leq C-M \leq 1.15.$$

In still another preferred embodiment, when the core is compressed under a final load of 1,275 N (130 kgf) from an initial load of 98 N (10 kgf) and the deflection (mm) is denoted by C (mm), the following condition is satisfied:

$$400 \leq Ciw/C \leq 850.$$

In a further preferred embodiment, the core has a hardness profile in which, letting the Shore C hardness at a core center be Cc, the Shore C hardness at a midpoint M between the core center and a core surface be C_m, the Shore C hardnesses at positions 2 mm, 4 mm, and 6 mm inward from the midpoint M be Cm−2, Cm−4, and Cm−6 respectively, the Shore C hardnesses at positions 2 mm, 4 mm, and 6 mm outward from the midpoint M be Cm+2, Cm+4, and Cm+6 respectively, and the Shore C hardness at the core surface be Cs, and defining surface areas A to F as follows:

surface area A: ½×2×(Cm−4−Cm−6)
surface area B: ½×2×(Cm−2−Cm−4)
surface area C: ½×2×(Cm−Cm−2)
surface area D: ½×2×(Cm+2−Cm)
surface area E: ½×2×(Cm+4−Cm+2)
surface area F: ½×2×(Cm+6−Cm+4)
the following condition is satisfied:

$$\{(\text{surface area } D+\text{surface area } E)-(\text{surface area } A+\text{surface area } B)\} \geq 2.0.$$

In a yet further preferred embodiment, the core has a hardness profile in which the following condition is satisfied:

$$(Cs-Cc) \geq 22.$$

In a still further preferred embodiment, the core has a hardness profile in which the following condition is satisfied:

$$(Cs-Cc)/(Cm-Cc) \geq 3.0.$$

In a yet further preferred embodiment, the core has a hardness profile in which the following condition is satisfied:

$$\text{surface area } E > \text{surface area } D > \text{surface area } C.$$

Advantageous Effects of the Invention

To address the possibility of there being a change to the rules in the future to suppress the distance by long hitters by the R&A and the USGA by changing the test conditions for the ODS of golf balls, with the golf ball of the present invention, instead of simply reducing the distance, making a distance for reducing the distance on shots with a driver by long hitters larger, and making the distance for reducing the distance on shots with a driver (W#1) by average hitters and the distance on shots with an iron by both long hitters and average hitters smaller may reduce an influence on play other than reducing the distance on shots with a driver by long hitters. In addition, the golf ball of the present invention has a similar performance to the ball used in the current tour with respect to its spin characteristics in the short game so that a sense of discomfort does not occur for professionals or advanced players when using the golf ball.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic cross-sectional view of a golf ball according to one embodiment of the present invention.

FIG. **2** is a graph that uses core hardness profile data in Example 4 to describe surface areas A to F in the core hardness profile.

FIG. **3** is a graph showing the core hardness profiles in Examples 1 to 4 and Comparative Example 4.

FIG. **4** is a graph showing the core hardness profiles in Comparative Examples 1 to 3, and 5 to 9.

FIG. **5** is a graph showing values of Ciw+Miw+CViw in Examples 1 to 4 and Comparative Examples 1 to 9.

FIGS. **6**A and **6**B show an arrangement mode (pattern) of dimples I to V used in Examples 1 to 4 and Comparative

Examples 1 to 8, where FIG. **6**A shows a plan view of the dimples, and FIG. **6**B shows a side view thereof.

FIGS. **7**A and **7**B show an arrangement mode (pattern) of dimples VI used in Comparative Example 9, where FIG. **7**A shows a plan view of the dimples, and FIG. **7**B shows a side view thereof.

DETAILED DESCRIPTION OF THE INVENTION

Hereinafter, the present invention is described in more detail.

A multi-piece solid golf ball according to the present invention has a core, an intermediate layer, and a cover, and an example thereof is shown in FIG. **1**, for example. A golf ball G shown in FIG. **1** has a single-layer core **1**, a single-layer intermediate layer **2** encasing the core **1**, and a single-layer cover **3** encasing the intermediate layer. The cover **3** is positioned at the outermost layer in the layer construction of the golf ball except for the coating layer. In addition to a single layer as shown in FIG. **1**, each layer of the core and the intermediate layer may be formed as a plurality of layers. A large number of dimples D are typically formed on the surface of the cover (outermost layer) **3** in order to improve the aerodynamic properties of the ball. In addition, although not particularly illustrated, a coating layer is typically formed on the surface of the cover **3**. Hereinafter, each of the above layers is described in detail.

The core is obtained by vulcanizing a rubber composition containing a rubber material as a chief material. If the core material is not a rubber composition, the rebound of the core may become low, and a desired distance may not be attainable on shots with a driver (W#1) and an iron by average hitters and on shots with an iron by long hitters. This rubber composition typically contains a base rubber as a chief material, and is obtained with the inclusion of a co-crosslinking agent, a crosslinking initiator, an inert filler, an organosulfur compound, or the like.

Examples of the core are preferably formed of a rubber composition containing, in particular, the following components (A) to (E):

(A) base rubber,

(B) co-crosslinking agent,

(C) water or monocarboxylic acid metal salt,

(D) organic peroxide, and

(E) organosulfur compound.

The base rubber (A) may include a diene rubber. Examples of the diene rubber include polybutadiene, natural rubber, isoprene rubber, and ethylene propylene diene rubber.

The co-crosslinking agent (B) is an α,β-unsaturated carboxylic acid and/or a metal salt thereof. Specific examples of the unsaturated carboxylic acid include acrylic acid, methacrylic acid, maleic acid, fumaric acid, or the like, and in particular, acrylic acid and methacrylic acid are suitably used. The metal salt of the unsaturated carboxylic acid is not particularly limited, and examples thereof include those obtained by neutralizing the unsaturated carboxylic acid with a desired metal ion. Specific examples thereof include zinc salts and magnesium salts such as methacrylic acid and acrylic acid, and in particular, zinc acrylate is suitably used.

The unsaturated carboxylic acid and/or the metal salt thereof is typically blended in an amount of at least 5 parts by weight, preferably at least 9 parts by weight, and even more preferably at least 13 parts by weight, and the upper limit is typically not more than 60 parts by weight, preferably not more than 50 parts by weight, and even more preferably not more than 40 parts by weight per 100 parts by weight of the base rubber. If the compounding amount is too large, the core may become too hard, giving the ball an unpleasant feel at impact, and if the compounding amount is too small, the rebound may become low.

The water (C) is not particularly limited and may be distilled water or tap water, in particular, it is suitable to employ distilled water free of impurities. The compounding amount of the water included per 100 parts by weight of the base rubber is preferably at least 0.1 parts by weight, and more preferably at least 0.2 parts by weight, and the upper limit is preferably not more than 2 parts by weight, and more preferably not more than 1 parts by weight.

By blending the water or a water-containing material as the component (C) directly into the core material, decomposition of the organic peroxide during the core formulation can be promoted. In addition, it is known that the decomposition efficiency of the organic peroxide in the core-forming rubber composition changes depending on temperature, and the decomposition efficiency increases as the temperature becomes higher than a certain temperature. If the temperature is too high, the amount of decomposed radicals becomes too large, and the radicals are recombined or deactivated. As a result, fewer radicals act effectively in crosslinking. Here, when decomposition heat is generated by the decomposition of the organic peroxide at the time of core vulcanization, a temperature near the core surface is maintained at substantially the same level as a temperature of a vulcanization mold, but the temperature around the core center is considerably higher than the mold temperature due to an accumulation of decomposition heat by the organic peroxide decomposing from the outside. If the water or a material containing water is directly included in the core, the water acts to promote the decomposition of the organic peroxide, so that the radical reactions as described above can be changed at the core center and the core surface. That is, the decomposition of the organic peroxide is further promoted near the core center, and the deactivation of radicals is further promoted, so that the amount of active radicals is further reduced, and as a result, a core can be obtained in which the crosslink densities at the core center and the core surface differ markedly, and the dynamic viscoelasticity of the core center portion is different.

In addition, a monocarboxylic acid metal salt can be employed instead of the water. In the monocarboxylic acid metal salt, it is presumed that a carboxylic acid is coordinate-bonded to the metal salt, and the monocarboxylic acid metal salt is distinguished from a dicarboxylic acid metal salt such as zinc diacrylate of $[CH_2{=}CHCOO]_2Zn$ in a chemical formula. The monocarboxylic acid metal salt brings water into the rubber composition by subjecting the monocarboxylic acid metal salt to a dehydration condensation reaction, so that the same effect as that of the water can be obtained. In addition, since the monocarboxylic acid metal salt can be blended in the rubber composition as powder, the working process can be simplified, and it is easy to uniformly disperse the monocarboxylic acid metal salt in the rubber composition. In order to effectively perform the above reaction, it is necessary to use a mono-salt. The compounding amount of the monocarboxylic acid metal salt is preferably at least 1 part by weight, and more preferably at least 3 parts by weight per 100 parts by weight of the base rubber. As the upper limit thereof, the compounding amount of the monocarboxylic acid metal salt is preferably not more than 60 parts by weight, and more preferably not more than 50 parts by weight. If the compounding amount of the monocarboxylic acid metal salt is too small, it is difficult to obtain an appropriate crosslinking density, and it may not be possible to obtain an adequate golf ball spin rate-lowering effect. In addition, if the compounding amount is too large, the core becomes too hard, so that it may be difficult to maintain an appropriate feel at impact.

As the carboxylic acid, an acrylic acid, a methacrylic acid, a maleic acid, a fumaric acid, a stearic acid, or the like may be used. Examples of a substitute metal include Na, K, Li, Zn, Cu, Mg, Ca, Co, Ni, and Pb, and Zn is preferably used. Specific examples thereof include a zinc monoacrylate and a zinc monomethacrylate, and it is particularly preferable to use a zinc monoacrylate.

As the organic peroxide (D), an organic peroxide having a relatively high thermal decomposition temperature is preferably used, and specifically, a high-temperature organic peroxide having a one-minute half-life temperature of about 165 to 185° C. is used, and examples thereof include a dialkyl peroxide. Examples of the dialkyl peroxide include a dicumyl peroxide ("PERCUMYL® D" manufactured by NOF Corporation), a 2,5-dimethyl-2,5-di(t-butylperoxy) hexane ("PERHEXA® 25B" manufactured by NOF Corporation), and a di(2-t-butylperoxyisopropyl) benzene ("PERBUTYL® P" manufactured by NOF Corporation), and a dicumyl peroxide may be suitably used. These may be used singly, or two or more may be used in combination. The half-life is one of the indices indicating a degree of a decomposition rate of the organic peroxide, and is indicated by a time required for the original organic peroxide to be decomposed and its active oxygen amount to reach ½. A vulcanization temperature in the rubber composition for the core is typically within a range of 120 to 190° C., and in that range, an organic peroxide having a one-minute half-life temperature of a high temperature, which is about 165° C. to 185° C., is thermally decomposed relatively slowly. With the rubber composition used in the present invention, by adjusting the amount of free radicals produced, which increases with the lapse of a vulcanization time, it is possible to obtain a core that is a rubber cross-linked product having a specific internal hardness shape described later.

The organosulfur compound (E) may be blended in order to control the rebound of the core so that it is increased. As the organosulfur compound, specifically, it is recommended to include thiophenol, thionaphthol, halogenated thiophenol, or a metal salt thereof. More specifically, examples of the organosulfur compound include zinc salts such as pentachlorothiophenol, pentafluorothiophenol, pentabromothiophenol, p-chlorothiophenol, and pentachlorothiophenol, and any of the following having 2 to 4 sulfur atoms: diphenylpolysulfide, dibenzylpolysulfide, dibenzoylpolysulfide, dibenzothiazoylpolysulfide, and dithiobenzoylpolysulfide. In particular, diphenyldisulfide and the zinc salt of pentachlorothiophenol is preferably used.

The upper limit of the compounding amount of the organosulfur compound is preferably not more than 5 parts by weight, more preferably not more than 4 parts by weight, further more preferably not more than 3 parts by weight, and most preferably not more than 2 parts by weight per 100 parts by weight of the base rubber. If the compounding amount is too large, the core hardness becomes too soft and the rebound of the core becomes too high, and the distance on shots with a driver by long hitters may be too large. On the other hand, the lower limit of the compounding amount is preferably at least 0.1 parts by weight, more preferably at least 0.2 parts by weight, and even more preferably at least 0.5 parts by weight per 100 parts by weight of the base rubber. If the compounding amount is too small, the rebound of the core may be too low, so that the distance on shots with a driver by average hitters and with an iron by both long hitters and average hitters may be largely lowered.

In the rubber composition, a filler, an antioxidant, and the like can be blended as components other than the components (A) to (E).

As a filler, for example, zinc oxide, barium sulfate, calcium carbonate, or the like may be suitably used. These may be used singly, or two or more may be used in combination. The compounding amount of the filler may be preferably at least 4 parts by weight, and more preferably at least 8 parts by weight, and even more preferably at least 12 parts by weight per 100 parts by weight of the base rubber. In addition, the upper limit of the compounding amount is preferably not more than 50 parts by weight, more preferably not more than 40 parts by weight, and even more preferably not more than 30 parts by weight per 100 parts by weight of the base rubber. If the compounding amount is too large or too small, it may not be possible to obtain an appropriate weight and a suitable rebound.

As an antioxidant, for example, commercially available products such as Nocrac NS-6, Nocrac NS-30, Nocrac NS-200, and Nocrac MB (all manufactured by Ouchi Shinko Chemical Industrial Co., Ltd.) may be employed. These may be used singly, or two or more may be used in combination.

The compounding amount of the antioxidant is, although not particularly limited, preferably at least 0.05 parts by weight, and more preferably at least 0.1 parts by weight, and the upper limit is preferably not more than 1.0 part by weight, more preferably not more than 0.7 parts by weight, and even more preferably not more than 0.5 parts by weight per 100 parts by weight of the base rubber. If the compounding amount is too large or too small, a suitable core hardness gradient may not be attainable, and it may not be possible to obtain a suitable rebound, durability, and a spin rate-lowering effect on full shots.

The core can be manufactured by vulcanizing and curing the rubber composition containing the above components. For example, a molded body can be manufactured by intensively mixing the rubber composition using a mixing apparatus such as a Banbury mixer or a roll mill, subsequently compression molding or injection molding the mixture using a core mold, and curing the resulting molded body by appropriately heating it at a temperature sufficient for the organic peroxide or the co-crosslinking agent to act, such as at a temperature of from 100 to 200° C., and preferably at a temperature of from 140 to 180° C., for from 10 to 40 minutes.

In the present invention, the core is formed as a single layer or a plurality of layers, although it is preferably formed as a single layer. If the rubber core is produced as a plurality of layers of rubber, layer separation at the interfaces may arise when the ball is repeatedly struck, possibly leading to a cracking in earlier timing.

The diameter of the core is preferably at least 36.7 mm, more preferably at least 37.3 mm, and even more preferably at least 37.9 mm. The upper limit of the diameter of the core is preferably not more than 40.0 mm, more preferably not more than 39.2 mm, and even more preferably not more than 38.5 mm. If the diameter of the core is too small, the initial velocity of the ball may become too low, or a deflection of the entire ball may become small, so that the spin rate of the ball on full shots may rise, and a desired distance may not be attainable on shots with a driver (W#1) by average hitters and on shots with an iron by both average hitters and long hitters. On the other hand, if the diameter of the core is too large, the spin rate on full shots may rise, and the desired distance of average hitters may not be attainable, or a durability to cracking on repeated impact may worsen.

The deflection (mm) when the core is compressed under a final load of 1,275 N (130 kgf) from an initial load of 98 N (10 kgf) is, although not particularly limited, preferably at least 3.5 mm, more preferably at least 3.7 mm, and even more preferably at least 4.0 mm. The upper limit is preferably not more than 5.0 mm, more preferably not more than 4.7 mm, and even more preferably not more than 4.5 mm. If the deflection of the core is too small, that is, the core is too hard, and a desired distance may not be attainable on shots with a driver (W#1) by average hitters and on shots with an iron by both average hitters and long hitters, or the feel at impact may be excessively hard. On the other hand, if the deflection of the core is too large, that is, if the core is too soft, the ball rebound may become too low and a good distance may not be achieved for average hitters, or the feel at impact may be too soft, or the durability to cracking on repeated impact may worsen.

Next, the core hardness profile is described. The hardness of the core described below means Shore C hardness. The Shore C hardness is a hardness value measured with a Shore C durometer conforming to the ASTM D2240 standard.

A core center hardness (Cc) is preferably at least 49, more preferably at least 51, and even more preferably at least 53. The upper limit is preferably not more than 62, more preferably not more than 60, and even more preferably not more than 58. If this value is too large, the spin rate of the ball on full shots may rise, so that a desired distance may not be attainable on shots with a driver (W#1) by average hitters and on shots with an iron by both average hitters and long hitters, or the feel at impact may be excessively hard. On the other hand, if the above value is too small, the rebound may become low and a desired distance for average hitters may not be attainable, or the durability to cracking on repeated impact may worsen.

Although not particularly limited, a hardness (Cm−6) at a position 6 mm inward from the point M (hereinafter, also referred to as "midpoint M") between the core center and the core surface may be preferably at least 51, more preferably at least 53, and even more preferably at least 55, and the upper limit is also not particularly limited, and may be preferably not more than 64, more preferably not more than 62, and even more preferably not more than 60. Hardnesses that deviate from these values may lead to undesirable results similar to those described above for the core center hardness (Cc).

Although not particularly limited, a hardness (Cm−4) at a position 4 mm inward from the point M (hereinafter, also referred to as "midpoint M") between the core center and the core surface may be preferably at least 52, more preferably at least 54, and even more preferably at least 56. The upper limit is also not particularly limited, and may be preferably not more than 65, more preferably not more than 63, and even more preferably not more than 61. Hardnesses that deviate from these values may lead to undesirable results similar to those described above for the core center hardness (Cc).

Although not particularly limited, a hardness (Cm−2) at a position 2 mm inward from the midpoint M of the core may be preferably at least 53, more preferably at least 55, and even more preferably at least 57. The upper limit is also not particularly limited, and may be preferably not more than 66, more preferably not more than 64, and even more preferably not more than 62. Hardnesses that deviate from these values may lead to undesirable results similar to those described above for the core center hardness (Cc).

Although not particularly limited, a cross-sectional hardness (Cm) at the midpoint M of the core may be preferably at least 54, more preferably at least 56, and even more preferably at least 58. In addition, although not particularly limited, the upper limit may be preferably not more than 65, more preferably not more than 63, and even more preferably not more than 61. Hardnesses that deviate from these values may lead to undesirable results similar to those described above for the core center hardness (Cc).

The core surface hardness (Cs) is preferably at least 76, more preferably at least 78, and even more preferably at least 80. The upper limit is preferably not more than 90, more preferably not more than 88, and even more preferably not more than 86. If this value is too large, the durability to cracking on repeated impact may worsen, or the feel at impact may be too hard. On the other hand, if this value is too small, the rebound may become low or the spin rate on full shots may rise, so that a desired distance may not be attainable on shots with a driver (W#1) by average hitters and on shots with an iron by both average hitters and long hitters.

A hardness (Cm+2) at a position 2 mm outward toward the core surface (hereinafter, simply referred to as "outward") from the midpoint M of the core may be, although not particularly limited, preferably at least 57, more preferably at least 59, and even more preferably at least 61. The upper limit is also not particularly limited, and may be preferably not more than 67, more preferably not more than 65, and even more preferably not more than 63. Hardnesses that deviate from these values may lead to undesirable results similar to those described above for the core surface hardness (Cs).

A hardness (Cm+4) at a position 4 mm outward from the midpoint M of the core may be, although not particularly limited, preferably at least 61, more preferably at least 63, and even more preferably at least 65. The upper limit also not particularly limited, and may be preferably not more than 72, more preferably not more than 70, and even more preferably not more than 68. Hardnesses that deviate from these values may lead to undesirable results similar to those described above for the core surface hardness (Cs).

A hardness (Cm+6) at a position 6 mm outward from the midpoint M of the core may be, although not particularly limited, preferably at least 68, more preferably at least 70, and even more preferably at least 72. The upper limit also not particularly limited, and may be preferably not more than 79, more preferably not more than 77, and even more preferably not more than 75. Hardnesses that deviate from these values may lead to undesirable results similar to those described above for the core surface hardness (Cs).

A value obtained by subtracting the core center hardness from the core surface hardness, that is, the value of Cs−Cc, is preferably at least 22, more preferably at least 24, and even more preferably at least 26. The upper limit is preferably not more than 35, more preferably not more than 32, and even more preferably not more than 29. If this value is too small, the spin rate of the ball on full shots may rise, so that a desired distance may not be attainable on shots with a driver (W#1) by average hitters and on shots with an iron by both average hitters and long hitters. On the other hand, if this value is too large, the rebound becomes low so that a desired distance may not be attainable on shots with a driver (W#1) by average hitters and on shots with an iron by both average hitters and long hitters, or the durability to cracking on repeated impact may worsen.

In addition, it is preferable to optimize the value of (Cs−Cc)/(Cm−Cc) for the core hardness profile. The value of (Cs−Cc) indicates a difference in hardness between the core center and the core surface, and a value of (Cm−Cc) indicates a difference in hardness between the core center and the midpoint between the core surface and the core center, and the above expression represents the ratio of these differences in hardness. The value of (Cs−Cc)/(Cm−Cc) is preferably at least 3.0, more preferably at least 4.0, and even more preferably at least 5.0. The upper limit is preferably not more than 12.0, more preferably not more than 11.0, and even more preferably not more than 9.5. If this value is too small, the spin rate on full shots may rise, and a desired distance may not be attainable on shots with a driver (W#1) by average hitters and on shots with an iron by both average hitters and long hitters. On the other hand, if this value is too large, the rebound becomes low so that a desired distance may not be attainable on shots with a driver (W#1) by average hitters and on shots with an iron by both average hitters and long hitters, or the durability to cracking on repeated impact may worsen.

In the core hardness profile, the surface areas A to F defined as follows:

surface area A: ½×2×(Cm−4−Cm−6)
surface area B: ½×2×(Cm−2−Cm−4)
surface area C: ½×2×(Cm−Cm−2)
surface area D: ½×2×(Cm+2−Cm)
surface area E: ½×2×(Cm+4−Cm+2)
surface area F: ½×2×(Cm+6−Cm+4)

are characterized in that a value of (surface area D+surface area E)−(surface area A+surface area B) is preferably at least 2.0, more preferably at least 3.0 or more, and even more preferably at least 3.5. The upper limit is preferably not more than 12.0, more preferably not more than 10.0, and even more preferably not more than 8.0. If this value is too small, the spin rate of the ball on full shots may rise, so that a desired distance may not be attainable on shots with a driver (W#1) by average hitters and on shots with an iron by both average hitters and long hitters. On the other hand, if this value is too large, the rebound becomes low so that a desired distance may not be attainable on shots with a driver (W#1) by average hitters and on shots with an iron by both average hitters and long hitters, or the durability to cracking on repeated impact may worsen.

In addition, the relationship of each surface area calculated from the core hardness profile preferably satisfies the flowing condition:

$$\text{area } E > \text{area } D > \text{area } C.$$

If this relational expression is not satisfied, the spin rate on full shots may rise, and a desired distance may not be attainable on shots with a driver (W#1) by average hitters and on shots with an iron by both average hitters and long hitters.

Further, it is preferable to optimize the value of the following condition:

$$\{(\text{surface area } D+\text{surface area } E)-(\text{surface area } A+\text{surface area } B)\}\times(Cs-Cc).$$

This value is at least 80, preferably at least 90, and more preferably at least 100. The upper limit is preferably not more than 220, more preferably not more than 200, and even more preferably not more than 190. If this value is too small, the spin rate of the ball on full shots may rise, so that a desired distance may not be attainable on shots with a driver (W#1) by average hitters and on shots with an iron by both average hitters and long hitters. On the other hand, if this value is too large, the rebound becomes low so that a desired distance may not be attainable on shots with a driver (W#1) by average hitters and on shots with an iron by both average hitters and long hitters, or the durability to cracking on repeated impact may worsen.

FIG. **2** shows a graph describing the surface areas A to F using the core hardness profile data of Example 4. In this way, the surface areas A to F are surface areas of each triangle whose base is a difference between each specific distance and whose height is a difference in hardness between each position at these specific distances.

An initial velocity of the core is preferably at least 75.0 m/s, more preferably at least 75.8 m/s, and even more preferably at least 76.2 m/s. The upper limit is not more than 78.0 m/s, preferably not more than 77.2 m/s, and more preferably not more than 76.6 m/s. If this initial velocity value is too high, the extent to which the distance with respect to the current tour ball is reduced on shots with a driver by long hitters is inadequate, and there is a possibility that the distance is too large compared with the standard distance of the new distance rules assumed by the R&A and the US GA. On the other hand, if the initial velocity is too low, a desired distance may not be attainable on shots with a driver (W#1) by average hitters and on shots with an iron by both average hitters and long hitters. The value of the initial velocity in this case is a numerical value measured by a device for measuring a coefficient of restitution (hereinafter, COR) of the same type as the R&A. Specifically, a device for measuring a COR manufactured by Hye Precision USA is used. As a condition, at the time of measurement, an air pressure is changed in four stages and measured, a relational expression between the incident velocity and the COR is constructed, and the initial velocity at an incident velocity of 43.83 m/s is determined from the relational expression. For a measurement environment of the device for measuring a COR, a ball temperature-controlled for at least three hours in a thermostatic bath adjusted to 23.9±1° C. is used, and measurement is performed at a room temperature of 23.9±2° C. In addition, a barrel diameter is selected such that a clearance on one side with respect to an outer diameter of the object being measured is from 0.2 to 2.0 mm.

When the initial velocity of the core is denoted by Vc (m/s), and the deflection is denoted by C (mm) when the core is compressed under a final load of 1,275 N (130 kgf) from an initial load of 98 N (10 kgf), the value of Vc/C is preferably at least 15, more preferably at least 16, and even more preferably at least 17. The upper limit is preferably not more than 25, more preferably not more than 23, and even more preferably not more than 20. If this value is too large, the extent to which the distance with respect to the current tour ball is reduced on shots with a driver by long hitters is inadequate, and there is a possibility that the distance is too large compared with the standard distance of the new distance rules assumed by the R&A and the US GA. On the other hand, if the value is too small, a desired distance may not be attainable on shots with a driver (W#1) by average hitters and on shots with an iron by both average hitters and long hitters.

When the value of (initial velocity of core×weight of core) is denoted by Ciw, Ciw means a value indicating the rebound of the core material portion in relation to its parts by weight. Ciw is preferably at least 2,490, more preferably at least 2,520, and even more preferably at least 2,550. The upper limit is preferably not more than 2,650, more preferably not more than 2,630 and even more preferably not more than 2,600. If this value is too large, the distance on shots with a driver (W#1) by long hitters may be larger than the intended distance, or the distance on shots with an iron may be smaller than the intended distance. On the other hand, if this value is too small, the distance on shots with a driver (W#1) by average hitters may be smaller than the intended distance.

When the core is compressed under a final load of 1,275 N (130 kgf) from an initial load of 98 N (10 kgf) and the deflection (mm) is denoted by C (mm), the value of Ciw/C means a distribution amount with respect to a certain deflection in a quantitative index obtained by multiplying the rebound of the core material portion and its parts by weight. Ciw/C is preferably at least 400, more preferably at least 500, and even more preferably at least 550. The upper limit is preferably not more than 850, more preferably not more than 750, and even more preferably not more than 650. If this value is too large, the distance on shots with a driver (W#1) by long hitters may be larger than the intended distance, or the distance on shots with an iron may be smaller than the intended distance. On the other hand, if this value is too small, the distance on shots with a driver (W#1) by average hitters may be smaller than the intended distance.

Next, the intermediate layer is described.

The intermediate layer has a material hardness on the Shore C hardness scale which, although not particularly limited, is preferably at least 90, more preferably at least 92, and even more preferably at least 93. The upper limit is preferably not more than 100, more preferably not more than 98, and even more preferably not more than 96. The surface hardness on the Shore D hardness scale is preferably at least 61, more preferably at least 63, and even more preferably at least 65. The upper limit is preferably not more than 72, more preferably not more than 70, and even more preferably not more than 67.

The sphere obtained by encasing the core with the intermediate layer (intermediate layer-encased sphere) has a surface hardness which, on the Shore C hardness scale, is preferably at least 95, more preferably at least 96, and even more preferably at least 97. The upper limit is preferably not more than 100, more preferably not more than 99, and even more preferably not more than 98. The surface hardness on the Shore D hardness scale is preferably at least 68, more preferably at least 69, and even more preferably at least 70. The upper limit is preferably not more than 78, more preferably not more than 75, and even more preferably not more than 72.

If the material hardness and the surface hardness of the intermediate layer are too soft in comparison with the above ranges, the spin rate may rise excessively on full shots, or an actual initial velocity on shots may become low, so that the distance on shots with a driver (W#1) by average hitters and an iron by both average hitters and long hitters may not be increased. On the other hand, if the material hardness and the surface hardness of the intermediate layer are too hard in comparison with the above ranges, the durability to cracking on repeated impact may worsen, or the feel at impact on shots with a putter or on short approaches may become too hard.

The intermediate layer has a thickness which is preferably at least 1.0 mm, more preferably at least 1.2 mm, and even more preferably at least 1.4 mm. On the other hand, the intermediate layer thickness has the upper limit that is preferably not more than 2.0 mm, more preferably not more than 1.8 mm, and even more preferably not more than 1.6 mm. It is preferable for the intermediate layer to be thicker than the subsequently described cover. If the intermediate layer thickness falls outside of the above ranges or is thinner than that of the cover, the spin rate-lowering effect on shots with a driver (W#1) may be inadequate, and the intended distance on full shots by average hitters and on shots with an iron by both long hitters and average hitters may not be increased. Also, when the intermediate layer is too thin, the durability to cracking on repeated impact may worsen. On the other hand, if the thickness of the intermediate layer is too thick than the above range, the feel at impact may worsen.

The value obtained by subtracting the cover thickness from the intermediate layer thickness is preferably larger than 0 mm, more preferably at least 0.2 mm, and even more preferably at least 0.4 mm. The upper limit is preferably not more than 1.2 mm, more preferably not more than 0.9 mm, and even more preferably not more than 0.7 mm. If this value deviates from the above ranges, the spin rate of the ball on full shots rises, the actual initial velocity on shots becomes lower, or the like, so that the distance on shots with a driver (W#1) by average hitters and on shots with an iron by both average hitters and long hitters may not be increased. On the other hand, if this value is too small, the durability to cracking on repeated impact may worsen.

As a material of the intermediate layer, it is suitable to employ an ionomer resin as a chief material. If an ionomer resin is employed as the chief material, an aspect that uses in admixture a zinc-neutralized ionomer resin and a sodium-neutralized ionomer resin as the chief materials is desirable. The blending ratio in terms of zinc-neutralized ionomer resin/sodium-neutralized ionomer resin (weight ratio) is from 5/95 to 95/5, preferably from 10/90 to 90/10, and more preferably from 15/85 to 85/15. If the zinc-neutralized ionomer and the sodium-neutralized ionomer are not included in this ratio, the rebound may become too low and the distance on shots with a driver (W#1) by average hitters and on shots with an iron by both long hitters and average hitters may not be increased, and further, the durability to cracking on repeated impact at room temperature may worsen, and the durability to cracking at a low temperature (below zero) may worsen.

In the intermediate layer material, an optional additive may be appropriately included depending on the intended use. For example, various additives such as a pigment, a dispersant, an antioxidant, an ultraviolet absorber, and a light stabilizer can be included. If these additives are included, the compounding amount thereof is preferably at least 0.1 parts by weight, and more preferably at least 0.5 parts by weight, and the upper limit is preferably not more than 10 parts by weight, and more preferably not more than 4 parts by weight per 100 parts by weight of the base resin.

For the intermediate layer material, it is suitable to abrade the surface of the intermediate layer in order to increase the degree of adhesion to a polyurethane suitably used in a cover material described later. Further, it is preferable that a primer (adhesive agent) is applied to the surface of the intermediate layer after the abrasion treatment, or an adhesion reinforcing agent is added to the intermediate layer material.

When the sphere (intermediate layer-encased sphere) in which the core is encased with the intermediate layer is compressed under a final load of 1,275 N (130 kgf) from an initial load of 98 N (10 kgf), the deflection (mm) is preferably at least 2.6 mm, more preferably at least 2.8 mm, and even more preferably at least 3.0 mm. The deflection upper limit is preferably not more than 4.2 mm, more preferably not more than 3.9 mm, and even more preferably not more than 3.6 mm. If the deflection of the intermediate layer-encased sphere is too small, that is, if the sphere is too hard, the spin rate of the ball rises and the distance on shots with a driver (W#1) by average hitters and on shots with an iron by both long hitters and average hitters may not be increased, or the feel at impact may be too hard. On the other hand, if the deflection is too large, that is, if the sphere is too soft, the spin rate decreases and a run increases too much on shots with an iron, it may be difficult to control the desired distance, the feel at impact may be too soft, or the durability to cracking on repeated impact may worsen.

The sphere (intermediate layer-encased sphere) in which the core is encased with the intermediate layer has an initial velocity which is preferably at least 76.0 m/s, more preferably at least 76.5 m/s, and even more preferably at least 77.0 m/s. The upper limit is preferably not more than 78.5 m/s, more preferably not more than 78.0 m/s, and even more preferably not more than 77.7 m/s. If this initial velocity value is too high, the extent to which the distance with respect to the current tour ball is reduced on shots with a driver by long hitters is inadequate, and there is a possibility that the distance is too large compared with the standard distance of the new distance rules assumed by the R&A and the USGA. On the other hand, if the initial velocity is too low, the distance on shots with a driver (W#1) by average hitters and on shots with an iron by both long hitters and average hitters may not be increased. The value of the initial velocity in this case is the same as the device and conditions used in the measurement of the initial velocity of the core described above.

When the initial velocity of the intermediate layer-encased sphere is denoted by V_M (m/s), and the deflection is denoted by M (mm) when the intermediate layer-encased sphere is compressed under a final load of 1,275 N (130 kgf) from an initial load of 98 N (10 kgf), a value of V_M/M is preferably at least 17, more preferably at least 19, and even more preferably at least 21. The upper limit is preferably not more than 29, more preferably not more than 27, and even more preferably not more than 25. If this value is too large, the extent to which the distance with respect to the current tour ball is reduced on shots with a driver by long hitters is inadequate, and there is a possibility that the distance is too large compared with the standard distance of the new distance rules assumed by the R&A and the US GA. On the other hand, if this value is too small, the distance on shots with a driver (W#1) by average hitters may become too small.

In addition, it is preferable to optimize a value (Miw) of [(initial velocity of intermediate layer-encased sphere−initial velocity of core)×(weight of intermediate layer-encased sphere−weight of core)], which is a relational expression of the initial velocity (m/s) of the core, the initial velocity (m/s) of the intermediate layer-encased sphere, the weight (g) of the core, and the weight (g) of the intermediate layer-encased sphere. This value means a value indicating a rebound of the intermediate layer material portion in relation to its parts by weight. The Miw value is preferably at least 1, more preferably at least 4, and even more preferably at least 7. The upper limit is preferably not more than 15, more preferably not more than 13, and even more preferably not more than 10. If this value is too large, the durability to repeated impact may worsen. On the other hand, if this value is too small, the spin rate of the ball on full shots may rise, and the distance on shots with a driver (W#1) by average hitters and on shots with an iron by both average hitters and long hitters may not be increased.

Next, the cover is described.

The cover has a material hardness on the Shore C hardness scale which, although not particularly limited, is preferably at least 50, more preferably at least 57, and even more preferably at least 63. The upper limit is preferably not more than 86, more preferably not more than 74, and even more preferably not more than 71. The surface hardness on the Shore D hardness scale is preferably at least 30, more preferably at least 35, and even more preferably at least 40. The upper limit is preferably not more than 57, more preferably not more than 53, and even more preferably not more than 50.

The sphere (ball) obtained by encasing the intermediate layer-encased sphere with the cover, has a surface hardness which, on the Shore C hardness scale, is preferably at least 73, more preferably at least 78 and even more preferably at least 83. The upper limit is preferably not more than 95, more preferably not more than 92 and even more preferably not more than 90. The surface hardness on the Shore D hardness scale is preferably at least 50, more preferably at least 53 and even more preferably at least 56. The upper limit is preferably not more than 70, more preferably not more than 65 and even more preferably not more than 60.

If the material hardness and the surface hardness of the cover are too soft in comparison with the above ranges, the spin rate on full shots may rise, and the distance on shots with a driver (W#1) by average hitters and on shots with an iron by both average hitters and long hitters may not be increased. On the other hand, if the material hardness and the surface hardness of the cover are too hard in comparison with the above ranges, the ball may not be fully receptive to spin on approach shots, or a scuff resistance may worsen.

The cover has a thickness of preferably at least 0.3 mm, more preferably at least 0.5 mm, and even more preferably at least 0.6 mm. The upper limit in the cover thickness is preferably not more than 1.2 mm, more preferably not more than 0.9 mm, and even more preferably not more than 0.8 mm. If the cover is too thick, the rebound of the ball on full shots is inadequate or the spin rate may rise, and accordingly the distance on shots with a driver (W#1) by average hitters and on shots with an iron by both average hitters and long hitters may not be increased. On the other hand, when the cover is too thin, the scuff resistance may worsen or the ball may not be receptive to spin on approach shots and may thus lack sufficient controllability.

As the cover material, various urethane resins used as a cover material in golf balls may be used from the viewpoints of spin controllability and scuff resistance in the short game. Furthermore, from the viewpoint of mass productivity, it is preferable to use a resin material mainly composed of a thermoplastic polyurethane. Further, the cover is suitably formed of a resin blend containing (I) a thermoplastic polyurethane and (II) a polyisocyanate compound as principal components.

The total weight of the components (I) and (II) is recommended to be at least 60%, and more preferably at least 70% with respect to the total amount of the resin composition of the cover. The components (I) and (II) are described in detail below.

Describing the thermoplastic polyurethane (I), the construction of the thermoplastic polyurethane includes a soft segment composed of a polymeric polyol (polymeric glycol), which is a long-chain polyol, and a hard segment composed of a chain extender and a polyisocyanate compound. Here, as the long-chain polyol serving as a starting material, any of those hitherto used in the art related to thermoplastic polyurethane can be used, and are not particularly limited, and examples thereof can include polyester polyol, polyether polyol, polycarbonate polyol, polyester polycarbonate polyol, polyolefin polyol, conjugated diene polymer-based polyol, castor oil-based polyol, silicone-based polyol, and vinyl polymer-based polyol. These long-chain polyols may be used singly, or two or more may be used in combination. Among them, a polyether polyol is preferable from the viewpoint that a thermoplastic polyurethane having a high rebound resilience and excellent low-temperature properties can be synthesized.

As the chain extender, those hitherto used in the art related to thermoplastic polyurethanes can be suitably used, and for example, a low-molecular-weight compound having on the molecule at least two active hydrogen atoms capable of reacting with an isocyanate group and having a molecular weight of not more than 400 is preferable. Examples of the chain extender include, but are not limited to, 1,4-butylene glycol, 1,2-ethylene glycol, 1,3-butanediol, 1,6-hexanediol, 2,2-dimethyl-1,3-propanediol, or the like. Among them, the chain extender is preferably an aliphatic diol having from 2 to 12 carbon atoms, and is more preferably 1,4-butylene glycol.

As the polyisocyanate compound, those hitherto used in the art related to thermoplastic polyurethane can be suitably used, and are not particularly limited. Specifically, one or more selected from the group consisting of 4,4'-diphenylmethane diisocyanate, 2,4-toluene diisocyanate (or) 2,6-toluene diisocyanate, p-phenylene diisocyanate, xylylene diisocyanate, 1,5-naphthylene diisocyanate, tetramethylxylene diisocyanate, hydrogenated xylylene diisocyanate, dicyclohexylmethane diisocyanate, tetramethylene diisocyanate, hexamethylene diisocyanate, isophorone diisocyanate, norbornene diisocyanate, trimethylhexamethylene diisocyanate, and dimer acid diisocyanate can be used. However, it may be difficult to control a crosslinking reaction during injection molding depending on the type of isocyanate. In the present invention, 4,4'-diphenylmethane diisocyanate, which is an aromatic diisocyanate, is most preferable from the viewpoint of providing a balance between stability during production and the physical properties to be manifested.

As specific examples of the thermoplastic polyurethane serving as the component (I), commercially available products can be used such as Pandex T-8295, Pandex T-8290, and Pandex T-8260 (all manufactured by DIC Covestro Polymer, Ltd.).

Although not an essential component, a thermoplastic elastomer other than the thermoplastic polyurethane can be included as a separate component (III) with the components (I) and (II). By including the component (III) in the resin blend, a flowability of the resin blend can be further improved, and various physical properties required of the golf ball cover material can be increased, such as a rebound and scuff resistance.

A compositional ratio of the components (I), (II), and (III) is not particularly limited, but in order to sufficiently and effectively exhibit the advantageous effects of the present invention, the compositional ratio (I):(II):(III) is preferably in the weight ratio range of from 100:2:50 to 100:50:0, and more preferably from 100:2:50 to 100:30:8.

Furthermore, various additives other than the components constituting the thermoplastic polyurethane may be included in the resin blend as necessary, and for example, a pigment, a dispersant, an antioxidant, a light stabilizer, an ultraviolet absorber, an internal mold lubricant, or the like may be appropriately included.

The manufacture of a multi-piece solid golf ball in which the above-described core, intermediate layer, and cover (outermost layer) are formed as successive layers can be performed by a customary method such as a known injection molding process. For example, an intermediate layer material is injected around the core in an injection mold to obtain an intermediate layer-encased sphere, and finally, a cover material, which is the outermost layer, is injection molded to obtain a multi-piece golf ball. In addition, it is also possible to produce a golf ball by preparing two half-cups pre-molded into hemispherical shapes, enclosing the core and the intermediate layer-encased sphere within the two half cups, and molding the core and the intermediate layer-encased sphere under applied heat and pressure. When the golf ball is compressed under a final load of 1,275 N (130 kgf) from an initial load of 98 N (10 kgf), the deflection (mm) is preferably at least 2.7 mm, more preferably at least 2.8 mm, and even more preferably at least 2.9 mm. The deflection upper limit is preferably not more than 3.7 mm, more preferably not more than 3.5 mm, and even more preferably not more than 3.3 mm. If the deflection of the golf ball is too small, that is, if the ball is too hard, the spin rate rises and the distance on shots with a driver (W#1) by average hitters and on shots with an iron by both long hitters and average hitters may not be increased, or the feel at impact may be too hard. On the other hand, if the deflection is too large, that is, if the sphere is too soft, the spin rate decreases and a run increases too much on shots with an iron, it may be difficult to control the desired distance, the feel at impact may be too soft, or the durability to cracking on repeated impact may worsen.

The initial velocity of the sphere (ball) in which the intermediate layer-encased sphere is encased with the cover is preferably at least 76.5 m/s, more preferably at least 76.7 m/s, and even more preferably at least 76.9 m/s. The upper limit is not more than 77.724 m/s. If this initial velocity value is too high, the official rules of R&A and USGA are not satisfied. On the other hand, if the initial velocity is too low, the distance on shots with a driver (W#1) by average hitters and on shots with an iron by both long hitters and average hitters may not be increased. The initial velocity value in this case is measured with the same device and under the same conditions as described above for measurement of the initial velocities of the core and the intermediate layer-encased sphere.

When the initial velocity of the ball is denoted by V (m/s), and the deflection (mm) is denoted by B (mm) when the ball is compressed under a final load of 1,275 N (130 kgf) from an initial load of 98 N (10 kgf), the value of V/B is preferably at least 20, more preferably at least 21, and even more preferably at least 23. The upper limit is preferably not more than 28, more preferably not more than 27, and even more preferably not more than 26. If this value is too large, the extent to which the distance with respect to the current tour ball is reduced on shots with a driver by long hitters is inadequate, and there is a possibility that the distance may be too large compared with the standard distance of the new distance rules assumed by the R&A and the US GA. On the other hand, if this value is too small, the distance on shots with a driver (W#1) by average hitters may become too small.

In addition, it is preferable to optimize the value (CViw) of [(initial velocity of ball−initial velocity of intermediate layer-encased sphere)×(weight of ball−weight of intermediate layer-encased sphere)], which is a relational expression of the initial velocity (m/s) of the intermediate layer-encased sphere, the initial velocity (m/s) of the ball, the weight (g) of the intermediate layer-encased sphere, and the weight (g) of the ball. This value means a value indicating a rebound of the cover material portion in relation to its parts by weight. The value of CViw is preferably at least −5, more preferably at least −4, and even more preferably at least −3. The upper limit is preferably not more than 0, more preferably not more than −1, and even more preferably not more than −2. If this value is too large, the controllability during a short game may be insufficient. On the other hand, if this value is too small, the spin rate on full shots may rise, and the distance on shots with a driver (W#1) by average hitters and on shots with an iron by both average hitters and long hitters may become too small.

Relationships Between Surface Hardnesses of Each Sphere

In the present invention, from the viewpoint that a relationship between the surface hardness of the intermediate layer-encased sphere and the surface hardness of ball is compatible with a superior distance on shots with a driver (W#1) by average hitters and on full shots with an iron by long hitters and controllability in the short game, the following condition needs to be satisfied:

(surface hardness of ball)<(surface hardness of intermediate layer-encased sphere).

Expressed on the Shore C hardness scale, a value obtained by subtracting the surface hardness of the ball from the surface hardness of the intermediate layer-encased sphere is preferably larger than 0, more preferably at least 4, and even more preferably at least 7. The upper limit is preferably not more than 20, more preferably not more than 16, and even more preferably not more than 12. When the above value is not more than 0, it may be difficult to achieve both the superior distance on shots with a driver by average hitters and on full shots with an iron by long hitters and controllability in the short game. On the other hand, if the value is too large, the distance on shots with a driver (W#1) by average hitters and on shots with an iron by both average hitters and long hitters may be smaller than the intended distance.

Expressed on the Shore C hardness scale, a value obtained by subtracting the core surface hardness from the surface hardness of the intermediate layer-encased sphere is preferably at least 5, more preferably at least 7, and even more preferably at least 10. The upper limit is preferably not more than 28, more preferably not more than 25, and even more preferably not more than 20. If this value deviates from the above range, the spin rate of the ball on full shots may rise, so that a desired distance may not be attainable on shots with a driver (W#1) by average hitters and on shots with an iron by both average hitters and long hitters.

Expressed on the Shore C hardness scale, a value obtained by subtracting the core center hardness from the surface hardness of the intermediate layer-encased sphere is preferably at least 30, more preferably at least 35, and even more preferably at least 38. The upper limit is preferably not more than 53, more preferably not more than 48, and even more preferably not more than 45. If the value is too small, the spin rate of the ball on full shots may rise, so that a desired distance may not be attainable on shots with a driver (W#1) by average hitters and on shots with an iron by both average hitters and long hitters. On the other hand, if the above value is too large, the durability to cracking on repeated impact may worsen, the actual initial velocity on shots becomes lower, a desired distance may not be attainable on shots with a driver (W#1) by average hitters.

Core Diameter and Ball Diameter

A relationship between the core diameter and the ball diameter, that is, a value of (core diameter)/(ball diameter) is preferably at least 0.859, more preferably at least 0.874, and even more preferably at least 0.888. The upper limit is preferably not more than 0.937, more preferably not more than 0.918, and even more preferably not more than 0.902. If this value is too small, the initial velocity of the ball may become too low, or a deflection of the entire ball may become small and the ball becomes too hard, and the spin rate on full shots may rise, and the distance on shots with a driver (W#1) by average hitters and on shots with an iron by both average hitters and long hitters may be shorter than the intended distance. On the other hand, if the value is too large, the spin rate of the ball on full shots may rise, the distance on shots with a driver (W#1) by average hitters and on shots with an iron by both average hitters and long hitters may be shorter than the intended distance, or the durability to cracking on repeated impact may worsen.

Relationships between Deflections of Each Sphere

When each sphere of the core and the ball is compressed under a final load of 1,275 N (130 kgf) from an initial load of 98 N (10 kgf) and the deflections (mm) are denoted by B (mm) and C (mm), respectively, a value of C−B is preferably at least 1.00 mm, more preferably at least 1.05 mm, and even more preferably at least 1.10 mm. The upper limit is preferably not more than 1.50 mm, more preferably not more than 1.40 mm, and even more preferably not more than 1.30 mm. If the above value is too large, the durability to cracking on repeated impact may worsen, the actual initial velocity on shots becomes lower, and a desired distance may not be attainable on shots with a driver (W#1) by average hitters. If this value is too small, the feel at impact may become too hard, or the spin rate on full shots may rise, so that a desired distance may not be attainable on shots with a driver (W#1) by average hitters and on shots with an iron by both average hitters and long hitters.

When each sphere of the core and the intermediate layer-encased sphere is compressed under a final load of 1,275 N (130 kgf) from an initial load of 98 N (10 kgf) and the deflections (mm) are denoted by C (mm) and M (mm), respectively, a value of C−M is preferably at least 0.65 mm, more preferably at least 0.80 mm, and even more preferably at least 0.90 mm. The upper limit is preferably not more than 1.15 mm, more preferably not more than 1.10 mm, and even more preferably not more than 1.00 mm. If the above value is too large, the durability to cracking on repeated impact may worsen, the actual initial velocity on shots becomes lower, and a desired distance may not be attainable on shots with a driver (W#1) by average hitters. If this value is too small, the feel at impact may become too hard, or the spin rate on full shots may rise, so that a desired distance may not be attainable on shots with a driver (W#1) by average hitters and on shots with an iron by both average hitters and long hitters.

Value of Ciw+Miw+CViw

In the golf ball of the present invention, when a value of (initial velocity of core×weight of core) is denoted by Ciw, a value of [(initial velocity of intermediate layer-encased sphere−initial velocity of core)×(weight of intermediate layer-encased sphere−weight of core)] is denoted by Miw, and a value of [(initial velocity of ball−initial velocity of intermediate layer-encased sphere)×(weight of ball−weight of intermediate layer-encased sphere)] is denoted by CViw, the following expression needs to be satisfied:

$$2500 \leq Ciw+Miw+CViw \leq 2650.$$

Ciw+Miw+CViw means a sum of the values indicating the rebound of each of the core, the intermediate layer material, and the cover material portion in relation to their parts by weight, and by designing the golf ball so as to satisfy the above expression, while reducing the distance on shots with a driver (W#1) by long hitters, it is possible to make the distance for reducing the distance on shots with a driver (W#1) or a long iron by average hitters smaller as compared with the distance for reducing the distance on shots by long hitters. The lower limit of Ciw+Miw+CViw is at least 2,500, preferably at least 2,540, and more preferably at least 2,580. The upper limit is not more than 2,650, preferably not more than 2,630, and more preferably not more than 2,610. If this value is too large, the distance in shot conditions with a driver (W#1) by long hitters may be too large, or a desired distance may not be attainable on shots with a driver (W#1) by average hitters and with an iron by both long hitters and average hitters. On the other hand, if the value is too small, a desired distance may not be attainable on shots with a driver (W#1) by average hitters and on shots with an iron by both long hitters and average hitters.

A large number of dimples may be formed on the outside surface of the cover. Although not particularly limited, the number of dimples arranged on the surface of the cover is preferably at least 280, preferably at least 300, and more preferably at least 310, and the upper limit thereof can be preferably not more than 450, more preferably not more than 400, and even more preferably not more than 350. If the number of dimples deviates from the above range, the distance on shots by a driver (W#1) by average hitters may be lowered.

As for the shape of the dimples, one type or a combination of two or more types such as a circular shape, various polygonal shapes, a dewdrop shape, and other oval shapes can be appropriately used. For example, if circular dimples are used, the diameter can be about at least 2.5 mm and not more than 6.5 mm, and the depth can be at least 0.08 mm and not more than 0.30 mm.

A dimple coverage ratio of the dimples on the spherical surface of the golf ball, specifically, a ratio (surface area coverage ratio, hereinafter, SR value) of a sum of the individual dimple surface areas, each defined by a flat plane circumscribed by an edge of a dimple, to a ball spherical surface area on the assumption that the ball has no dimples is preferable at least 75%, more preferably at least 80%, and even more preferably at least 84%. The upper limit is not more than 90%, more preferably not more than 88%, and even more preferably not more than 86%. If the SR value deviates from the above range, the distance on shots by a driver (W#1) by average hitters may be lowered.

A VR value of a sum of the volumes of the individual dimples, formed below the flat plane circumscribed by the edge of a dimple, to a ball spherical volume on the assumption that the ball has no dimples, is 0.75%, preferably at least 0.78%, more preferably at least 0.80%. The upper limit is not more than 0.89%, more preferably not more than 0.88%, more preferably not more than 0.86%. If this VR value is higher than the above range, there is a case where the distance on shots with a driver (W#1) by long hitters may be too small, or the intended distance on shots with a driver (W#1) by average hitters may not be attainable. In addition, in this case, a ball trajectory may become lower, it becomes difficult to carry, and it may become difficult to go over a valley or a pond. On the other hand, if the value is too small, the extent of reducing the distance on shots with a driver (W#1) by long hitters is inadequate, and there is a possibility that the distance is too large compared with the standard distance of the new distance rules assumed by the R&A and the US GA.

A value V_0 obtained by dividing the spatial volume of the dimples below the flat plane circumscribed by the edge of each dimple by a volume of a cylinder whose base is the flat plane and whose height is a maximum depth of the dimple from the base is preferably at least 0.35, more preferably at least 0.38, and further preferably at least 0.40. The upper limit is not more than 0.80, more preferably not more than 0.70, and even more preferably not more than 0.60. If the V_0 value deviates from the above range, the distance on shots with a driver (W#1) by long hitters and average hitters may be lowered.

The multi-piece solid golf ball of the invention can be made to conform to the Rules of Golf for play. The inventive ball may be formed to a diameter which is such that the ball does not pass through a ring having an inner diameter of 42.672 mm and to a weight which is preferably between 45.0 and 45.93 g.

EXAMPLES

Hereinafter, the present invention is specifically described with reference to Examples and Comparative Examples, but the present invention is not limited to the following Examples.

Example 1 to 4 and Comparative Examples 1 to 9

Formation of Core

In Examples 1 and 3 and Comparative Examples 1 to 4, 6, and 8, a rubber composition of each Example shown in Table 1 was prepared, and then vulcanization molding was performed under vulcanization conditions according to each Example shown in Table 1 to produce a solid core.

In Examples 2 and 4 and Comparative Examples 5, 7, and 9, cores are produced based on the formulations in Table 1 in the same manner as described above.

TABLE 1

Core formulation	Example				Comparative Example								
(pbw)	1	2	3	4	1	2	3	4	5	6	7	8	9
Polybutadiene A					64	64	64			100	100	35	95
Polybutadiene B	20	20	20					20	20				
Polybutadiene C	80	80	80					80	80				
Polybutadiene D				100									
Isoprene rubber													5
Styrene-butadiene rubber					36	36	36					65	
Zinc acrylate	33.5	33.5	33.5	36.5	31.0	29.0	27.0	33.5	33.5	37.0	37.0	26.9	
Zinc methacrylate										1	1	1	
Methacrylic acid													23.5
Zinc stearate	2	2	2					2	2				
Organic peroxide	1	1	1	0.6	0.6	0.6	0.6	1	1	1	1	1	1.2

TABLE 1-continued

Core formulation (pbw)		Example 1	Example 2	Example 3	Example 4	Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4	Comparative Example 5	Comparative Example 6	Comparative Example 7	Comparative Example 8	Comparative Example 9
Sulfur		0.025	0.025	0.025					0.025	0.025				
Water		0.6	0.6	0.6	0.8	0.8	0.8	0.8	0.6	0.6	0.4	0.4	0.4	
Antioxidant		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2
Zinc oxide		19.3	19.3	19.3	18.0	19.0	19.9	20.7	19.3	19.3	14.8	14.8	16.5	23.5
Barium sulfate														1
Zinc salt of pentachlorothiophenol		0.6	0.6	0.6	1.0				0.6	0.6	1.0	1.0		
Vulcanization	Temp. (° C.)	160	160	160	158	152	152	152	160	160	150	150	150	163
conditions	Time (min)	14	14	14	14	19	19	19	14	14	19	19	19	21

Details of the above formulations are as follows.
Polybutadiene A: Trade name "BR01" (manufactured by JSR Corporation)
Polybutadiene B: Trade name "Diene 645" (FIRESTONE POLYMERS)
Polybutadiene C: Trade name "BUDENE 1224 G" (Goodyear Tire & Rubber Company)
Polybutadiene D: Trade name "BR730" (manufactured by JSR Corporation)
Isoprene rubber: Trade name "IR 2200" (manufactured by JSR Corporation)
Styrene-butadiene rubber: Trade name "SBR 1507" (manufactured by JSR Corporation)
Zinc acrylate: Trade name "ZN-DA85S" (manufactured by Nippon Shokubai Co., Ltd.)
Zinc methacrylate: Trade name "ZDA-90" (manufactured by Asada Chemical Industry Co., Ltd.)
Zinc stearate: Trade name "BR-3T" (manufactured by Akrochem Corporation)
Organic peroxide: Dicumyl peroxide, trade name "Percumyl D" (manufactured by NOF Corporation)
Sulfur: Trade name "SANMIX S-80N" (manufactured by Sanshin Chemical Industry Co., Ltd., containing sulfur powder for rubber in an amount of 80 wt %)
Water: Pure water (manufactured by Seiki Co., Ltd.)
Antioxidant: 2,2-methylenebis(4-methyl-6-butylphenol), trade name "Nocrac NS-6" (manufactured by Ouchi Shinko Chemical Industrial Co., Ltd.)
Zinc oxide: Trade name "Grade 3 Zinc Oxide" (manufactured by Sakai Chemical Industry Co., Ltd.)
Zinc salt of pentachlorothiophenol: Manufactured by Wako Pure Chemical Industries, Ltd.

Formation of Intermediate Layer and Cover (Outermost Layer)

Next, in Examples 1 and 3 and Comparative Examples 1 to 4, 6, and 8, the intermediate layer was formed by injection molding the resin material No. 1 or No. 2 of the intermediate layer shown in Table 2 around the core surface using an injection mold. Subsequently, the cover was formed by injection molding the resin material No. 3 of the cover (outermost layer) shown in Table 2 around the intermediate layer-encased sphere using a separate injection mold. At this time, a large number of predetermined dimples described below were formed on the cover surface.

In Examples 2 and 4 and Comparative Examples 5 and 7, the intermediate layer is formed around the core surface by injection molding using the injection mold and the resin material No. 1 or No. 2 of the intermediate layer shown in Table 2. Subsequently, the cover is formed by injection molding the resin material No. 3 of the cover (outermost layer) shown in Table 2 around the intermediate layer-encased sphere using a separate injection mold. In Comparative Example 9, a cover is formed by injection molding a resin material No. 4 shown in Table 2 around the core surface using an injection molding mold. At this time, a large number of predetermined dimples described below are formed on the cover surface.

TABLE 2

Resin material (parts by weight)	Acid content (wt %)	Metal type	No. 1	No. 2	No. 3	No. 4
Himilan 1605	15	Na	50			
Himilan 1557	12	Zn	15			
Himilan 1706	15	Zn	35	15		
AM7318	18	Na		85		
Titanium oxide					3	3
Trimethylolpropane			1.1	1.1		
TPU (1)					100	
TPU (2)						100

Details of the blending components in Table 2 are as follows.

"Himilan 1605", "Himilan 1557", "Himilan 1706", and "AM7318", ionomer resins manufactured by Dow-Mitsui Polychemicals Co., Ltd.

"Trimethylolpropane" (TMP) manufactured by Tokyo Chemical Industry Co., Ltd.

"Pandex" ether-type thermoplastic polyurethane (TPU (1)), material hardness (Shore D) 50, manufactured by DIC Covestro Polymer Ltd.

"Pandex" ether-type thermoplastic polyurethane (TPU (2)), material hardness (Shore D) 47, manufactured by DIC Covestro Polymer Ltd.

For the dimples of Examples and Comparative Examples, the following dimple modes I to VI were used. Each dimple mode includes eight types of circular dimples of No. 1 to No. 8 having different diameters and depths. Details thereof are shown in Table 3 below (dimples I to VI). In addition, an arrangement mode (pattern) of the dimples I to V is illustrated in FIGS. **6**A and **6**B. FIG. **6**A is a plan view of the dimple, and FIG. **6**B is a side view thereof. In addition, an arrangement mode (pattern) of the dimple VI is illustrated in FIGS. **7**A and **7**B. FIG. **7**A is a plan view of the dimple, and FIG. **7**B is a side view thereof.

TABLE 3

	Type	Quantity	Diameter (mm)	Depth (mm)	Volume (mm^3)	Cylindrical volume ratio Vo	SR (%)	VR (%)
Dimple I	No. 1	12	4.63	0.122	1.009	0.491	84	0.68
	No. 2	198	4.50	0.119	0.919	0.486		
	No. 3	36	3.92	0.115	0.655	0.472		
	No. 4	12	2.87	0.086	0.245	0.442		
	No. 5	36	4.49	0.126	0.965	0.483		
	No. 6	24	3.92	0.124	0.711	0.473		
	No. 7	6	3.31	0.133	0.550	0.479		
	No. 8	6	3.21	0.132	0.457	0.430		
	Total	330						
Dimple II	No. 1	12	4.69	0.144	1.220	0.493	86	0.81
	No. 2	198	4.54	0.140	1.100	0.486		
	No. 3	36	3.96	0.134	0.766	0.467		
	No. 4	12	2.92	0.109	0.322	0.441		
	No. 5	36	4.54	0.146	1.141	0.485		
	No. 6	24	3.96	0.144	0.827	0.468		
	No. 7	6	3.36	0.136	0.590	0.491		
	No. 8	6	3.22	0.127	0.433	0.421		
	Total	330						
Dimple III	No. 1	12	4.69	0.146	1.236	0.490	86	0.83
	No. 2	198	4.54	0.143	1.122	0.484		
	No. 3	36	3.96	0.137	0.790	0.470		
	No. 4	12	2.92	0.106	0.310	0.438		
	No. 5	36	4.54	0.149	1.162	0.482		
	No. 6	24	3.96	0.147	0.846	0.467		
	No. 7	6	3.38	0.138	0.608	0.493		
	No. 8	6	3.28	0.132	0.470	0.423		
	Total	330						
Dimple IV	No. 1	12	4.70	0.149	1.252	0.487	86	0.85
	No. 2	198	4.55	0.146	1.144	0.483		
	No. 3	36	3.97	0.140	0.815	0.472		
	No. 4	12	2.91	0.103	0.298	0.435		
	No. 5	36	4.55	0.152	1.183	0.480		
	No. 6	24	3.97	0.150	0.864	0.467		
	No. 7	6	3.40	0.140	0.627	0.495		
	No. 8	6	3.33	0.138	0.510	0.426		
	Total	330						
Dimple V	No. 1	12	4.68	0.164	1.391	0.493	85	0.93
	No. 2	198	4.53	0.161	1.258	0.485		
	No. 3	36	3.95	0.154	0.883	0.468		
	No. 4	12	2.90	0.114	0.331	0.440		
	No. 5	36	4.53	0.168	1.294	0.480		
	No. 6	24	3.95	0.165	0.949	0.470		
	No. 7	6	3.36	0.154	0.663	0.487		
	No. 8	6	3.26	0.152	0.538	0.426		
	Total	330						
Dimple VI	No. 1	24	4.48	0.171	1.233	0.459	75	0.77
	No. 2	174	4.29	0.164	1.073	0.452		
	No. 3	42	3.71	0.152	0.719	0.438		
	No. 4	12	2.87	0.121	0.327	0.419		
	No. 5	24	2.55	0.101	0.238	0.460		
	No. 6	30	4.33	0.179	1.160	0.440		
	No. 7	24	3.51	0.176	0.800	0.470		
	No. 8	8	3.30	0.145	0.520	0.418		
	Total	338						

Definition of Dimple

- Edge: highest point in cross section passing through center of a dimple
- Diameter: diameter of the flat plane circumscribed by the edge of a dimple
- Depth: maximum depth of a dimple from the flat plane circumscribed by the edge of the dimple
- SR: a ratio of a sum of the individual dimple surface areas, each defined by a flat plane circumscribed by an edge of a dimple, to a ball spherical surface area on the assumption that the ball has no dimples
- Dimple volume: a dimple volume under a flat plane circumscribed by an edge of a dimple
- Cylinder volume ratio: a ratio of the dimple volume to the cylinder volume having the same diameter as the dimple
- VR: a ratio of a sum of the volumes of the individual dimples, formed below the flat plane circumscribed by the edge of a dimple, to a ball spherical volume on the assumption that the ball has no dimples

For each resulting golf ball, various physical properties such as internal hardnesses at various positions of the core, outer diameters of the core and each layer-encased sphere, thicknesses and material hardnesses of each layer, surface hardnesses of each layer-encased sphere, and initial velocities of each ball are evaluated by the following methods, and are shown in Tables 4 to 7.

Core Hardness Profile

The core surface is spherical, but an indenter of a durometer is set substantially perpendicular to the spherical core surface, and a surface hardness of core expressed on the Shore C hardness scale is measured in accordance with ASTM D2240. With respect to the core center and a predetermined position of the core, the core is cut into hemispheres to obtain a flat cross-section, the hardness is measured by perpendicularly pressing the indenter of the durometer against the center portion and the predetermined positions shown in Table 3, and the hardness at the center and each position are shown as Shore C hardness values. For the measurement of the hardness, a P2 Automatic Rubber Hardness Tester manufactured by Kobunshi Keiki Co., Ltd. equipped with a Shore C durometer is used. For the hardness value, a maximum value is read. All measurements are carried out in an environment of 23±2° C. It is noted that the numerical values in the table are Shore C hardness values.

In addition, in the core hardness profile, letting Cc be the Shore C hardness at the core center, C m be the Shore C hardness at the midpoint M between the core center and the core surface, Cm−2, Cm−4, and Cm−6 be respective Shore C hardnesses at positions 2 mm, 4 mm, and 6 mm inward from the midpoint M, Cm+2, Cm+4, and Cm+6 be respective Shore C hardnesses at positions 2 mm, 4 mm, and 6 mm outward from the center M, and Cs be the Shore C hardness at the core surface, the surface areas A to F are calculated as follows:

surface area A: ½×2×(Cm−4−Cm−6)
surface area B: ½×2×(Cm−2−Cm−4)
surface area C: ½×2×(Cm−Cm−2)
surface area D: ½×2×(Cm+2−Cm)
surface area E: ½×2×(Cm+4−Cm+2)
surface area F: ½×2×(Cm+6−Cm+4)

and the values of the following four expressions are determined.

$$\text{Surface area } A + \text{Surface area } B \tag{1}$$

$$\text{Surface area } D + \text{Surface area } E \tag{2}$$

$$(\text{Area } D + \text{Area } E) - (\text{Area } A + \text{Area } B) \tag{3}$$

$$\{(\text{Surface area } D + \text{surface area } E) - (\text{Surface area } A + \text{surface area } B)\} \times (Cs - Cc) \tag{4}$$

The surface areas A to F in the core hardness profile are described in FIG. **2**, which shows a graph that illustrates surface areas A to F using the core hardness profile data from Example 4.

In addition, FIGS. **3** and **4** show graphs of core hardness profiles for Examples 1 to 4 and Comparative Examples 1 to 9.

Diameters of Core and of Intermediate Layer-Encased Sphere

At a temperature adjusted to 23.9±1° C. for at least three hours in a thermostatic bath, five random places on the surface are measured in a room with a temperature of 23.9±2° C., and, using an average value of these measurements as a measured value of each sphere, an average value for the diameter of 10 such spheres is determined.

Ball Diameter

At a temperature adjusted to 23.9±1° C. for at least three hours in a thermostatic bath, a diameter at 15 random dimple-free places is measured in a room at a temperature of 23.9±2° C., and, using an average value of these measurements as a measured value of one ball, an average value for the diameter of 10 balls is determined.

Deflections of Core, Intermediate Layer-Encased Sphere, and Ball

Each subject layer-encased sphere is placed on a hard plate, and a deflection when compressed under a final load of 1,275 N (130 kgf) from an initial load of 98 N (10 kgf) is measured. Note that the deflection in each case is a measurement value measured in a room at a temperature of 23.9±2° C. after temperature adjustment to 23.9±1° C. for at least three hours in a thermostatic bath. As a measuring device, a high-load compression tester manufactured by MU Instruments Trading Corp. is used, and the down speed of the pressure head that compresses the core, the encased sphere of each layer, or the ball is set to 10 mm/s.

Material Hardnesses of Intermediate Layer and Cover (Shore C and Shore D Hardnesses)

The resin material of each layer is molded into a sheet having a thickness of 2 mm and left at a temperature of 23±2° C. for two weeks. At the time of measurement, three such sheets are stacked together. The Shore C hardness and the Shore D hardness are each measured with a Shore C durometer and a Shore D durometer conforming to the ASTM D2240 standard. For the measurement of the hardness, the P2 Automatic Rubber Hardness Tester manufactured by Kobunshi Keiki Co., Ltd. to which a Shore C durometer or a Shore D durometer is mounted is used. For the hardness value, a maximum value is read. The measurement method is in accordance with the ASTM D2240 standard.

Surface Hardnesses of Each Sphere of Intermediate Layer-Encased Sphere and of Ball

A measurement is performed by perpendicularly pressing the indenter against the surface of each sphere. Note that a surface hardness of a ball (cover) is a measured value at a dimple-free area (land) on the surface of the ball. The Shore C hardness and the Shore D hardness are each measured with a Shore C durometer and a Shore D durometer conforming to the ASTM D2240 standard. For the measurement of the hardness, the P2 Automatic Rubber Hardness Tester manufactured by Kobunshi Keiki Co., Ltd. to which a Shore C durometer or a Shore D durometer is mounted is used. For the hardness value, a maximum value is read. The measurement method is in accordance with the ASTM D2240 standard.

Initial Velocity of Each Sphere

The initial velocity of each sphere is measured at a temperature of 23.9±2° C. using the device for measuring COR manufactured by Hye Precision Products of the same type as the R&A. The measurement principle is as follows.

An air pressure is changed to four stages of 35.5 psi, 36.5 psi, 39.5 psi, and 40.5 psi, and a ball is fired at four stages of incident velocity by respective air pressures, collided with a barrier, and its COR is measured. That is, a correlation equation between the incident velocity and the COR is created by changing the air pressure in four stages. Similarly, a correlation equation between the incident velocity and a contact time is created.

Then, from these correlation equations, the COR and the contact time (μs) at an incident velocity of 43.83 m/s are determined and substituted into the following initial velocity conversion equation to calculate an initial velocity of each sphere.

$$IV = 136.8 + 136.3e + 0.019tc$$

[Here, e is a coefficient of restitution, and tc is a contact time (μs) at a collision speed of 143.8 ft/s (43.83 m/s).]

In the measurement of the initial velocity of each sphere, a barrel diameter is selected such that a clearance on one side with respect to an outer diameter of the object being measured is from 0.2 to 2.0 mm. For the core, a barrel diameter of 39.88 mm is selected in Examples 1 to 4 and Comparative Examples 1 to 8, and a barrel diameter of 41.53 mm is selected in Comparative Example 9. A barrel of 41.53 mm in all examples is selected for the intermediate layer-encased sphere, and a barrel of 43.18 mm in all examples is selected for the ball.

Values of Ciw+Miw+CViw

In each example of the Examples and the Comparative Examples, a value of Ciw+Miw+CViw is calculated by assuming that a value of (initial velocity of core×weight of core) is denoted by Ciw, a value of [(initial velocity of intermediate layer-encased sphere−initial velocity of core)×(weight of intermediate layer-encased sphere−weight of core)] is denoted by Miw, and a value of [(initial velocity of ball−initial velocity of intermediate layer-encased sphere)×(weight of ball−weight of intermediate layer-encased sphere)] is denoted by CViw. The numerical values of each example are shown in Tables 6 and 7, and a graph showing the values of Ciw+Miw+CViw is shown in FIG. 5.

TABLE 4

		Example				Comparative Example		
		1	2	3	4	1	2	3
	Structure (Piece)	3P	3P	3P	3P	3P	3P	3P
Core	Outer diameter (mm)	38.06	38.06	38.06	38.11	38.01	38.03	38.00
	Weight (g)	33.83	33.83	33.83	33.95	33.74	33.77	33.74
	Deflection C (mm)	4.13	4.13	4.13	4.52	3.78	4.04	4.33
	Initial velocity (m/s)	76.44	76.44	76.44	76.4	73.78	73.68	73.55
	Initial velocity/deflection	18.5	18.5	18.5	16.9	19.5	18.2	17.0
	Initial velocity × Weight: Ciw	2,586	2,586	2,586	2,594	2,489	2,488	2,482
	Ciw/C	626	626	626	574	658	615	574
	Cs (Shore C)	86.3	86.3	86.3	79.7	80.7	77.2	74.8
	Cm + 6 (Shore C)	74.1	74.1	74.1	72.4	76.9	74.7	72.0
	Cm + 4 (Shore C)	65.9	65.9	65.9	67.6	74.5	72.6	70.4
	Cm + 2 (Shore C)	61.3	61.3	61.3	62.6	70.1	68.7	67.2
	Cm (Shore C)	61.0	61.0	61.0	58.5	64.3	63.4	62.5
	Cm − 2 (Shore C)	61.4	61.4	61.4	57.1	60.2	58.8	57.8
	Cm − 4 (Shore C)	61.0	61.0	61.0	56.1	59.0	56.4	55.4
	Cm − 6 (Shore C)	60.1	60.1	60.1	55.2	57.8	54.9	53.8
	Cc (Shore C)	57.9	57.9	57.9	53.6	57.1	54.0	52.4
	Cs − Cc (Shore C)	28.4	28.4	28.4	26.1	23.6	23.2	22.4
	(Cs − Cc)/(Cm − Cc)	9.2	9.2	9.2	5.3	3.3	2.5	2.2
	Surface area A	0.9	0.9	0.9	0.9	1.2	1.5	1.6
	Surface area B	0.4	0.4	0.4	1.0	1.2	2.4	2.4
	Surface area C	−0.4	−0.4	−0.4	1.4	4.1	4.6	4.7
	Surface area D	0.3	0.3	0.3	4.1	5.8	5.3	4.7
	Surface area E	4.6	4.6	4.6	5.0	4.4	3.9	3.2
	Surface area F	8.2	8.2	8.2	4.8	2.4	2.1	1.6
	Surface area A + surface area B	1.3	1.3	1.3	1.9	2.4	3.9	4.0
	Surface area D + surface area E	4.9	4.9	4.9	9.1	10.2	9.2	7.9
	(Surface areas: D + E) − (surface areas: A + B)	3.6	3.6	3.6	7.2	7.8	5.3	3.9
	{(Surface areas: D + E) − (surface areas: A + B)} × (Cs − Cc)	102	102	102	188	184	123	87

TABLE 5

		Comparative Example					
		4	5	6	7	8	9
	Structure (Piece)	3P	3P	3P	3P	3P	2P
Core	Outer diameter (mm)	38.06	38.06	38.65	38.65	38.64	39.80
	Weight (g)	33.83	33.83	35.09	35.09	35.10	36.99
	Deflection C (mm)	4.13	4.13	2.92	2.92	2.93	2.63
	Initial velocity (m/s)	76.44	76.44	76.70	76.70	72.61	73.54
	Initial velocity/deflection	18.5	18.5	26.3	26.3	24.8	28.0
	Initial velocity × Weight: Ciw	2,586	2,586	2,691	2,691	2,549	2,720
	Ciw/C	626	626	923	923	870	1036
	Cs (Shore C)	86.3	86.3	87.4	87.4	81.5	84.3
	Cm + 6 (Shore C)	74.1	74.1	80.4	80.4	80.5	79.0
	Cm + 4 (Shore C)	65.9	65.9	75.8	75.8	79.0	75.9
	Cm + 2 (Shore C)	61.3	61.3	70.8	70.8	76.2	72.8
	Cm (Shore C)	61.0	61.0	66.3	66.3	72.3	70.8
	Cm − 2 (Shore C)	61.4	61.4	65.6	65.6	68.4	69.8
	Cm − 4 (Shore C)	61.0	61.0	64.9	64.9	66.9	68.4
	Cm − 6 (Shore C)	60.1	60.1	63.3	63.3	65.4	66.3
	Cc (Shore C)	57.9	57.9	62.6	62.6	62.7	60.7
	Cs − Cc (Shore C)	28.4	28.4	24.8	24.8	18.8	23.6
	(Cs − Cc)/(Cm − Cc)	9.2	9.2	6.7	6.7	2.0	2.3

TABLE 5-continued

	Comparative Example					
	4	5	6	7	8	9
Surface area A	0.9	0.9	1.6	1.6	1.5	2.1
Surface area B	0.4	0.4	0.7	0.7	1.5	1.4
Surface area C	−0.4	−0.4	0.7	0.7	3.9	1.0
Surface area D	0.3	0.3	4.5	4.5	3.9	2.0
Surface area E	4.6	4.6	5.0	5.0	2.8	3.1
Surface area F	8.2	8.2	4.6	4.6	1.5	3.1
Surface area A + surface area B	1.3	1.3	2.3	2.3	3.0	3.5
Surface area D + surface area E	4.9	4.9	9.5	9.5	6.7	5.1
(Surface areas: D + E) − (surface areas: A + B)	3.6	3.6	7.2	7.2	3.7	1.6
{(Surface areas: D + E) − (surface areas: A + B)} × (Cs − Cc)	102	102	179	179	70	38

TABLE 6

		Example				Comparative Example		
		1	2	3	4	1	2	3
Intermediate layer	Material	No. 1	No. 1	No. 1	No. 1	No. 1	No. 1	No. 1
	Thickness (mm)	1.47	1.47	1.47	1.48	1.52	1.52	1.52
	Weight (g)	6.82	6.82	6.82	6.81	7.02	7.00	7.00
	Material hardness (Shore C)	94	94	94	94	94	94	94
	Material hardness (Shore D)	65	65	65	65	65	65	65
Intermediate layer-encased sphere	Outer diameter (mm)	41.00	41.00	41.00	41.06	41.04	41.06	41.04
	Weight (g)	40.65	40.65	40.65	40.76	40.76	40.77	40.74
	Deflection (mm)	3.20	3.20	3.20	3.53	3.04	3.27	3.52
	Initial velocity (m/s)	77.54	77.54	77.54	77.40	75.36	75.20	75.17
	Initial velocity/deflection	24.2	24.2	24.2	21.9	24.8	23.0	21.4
	Surface hardness (Shore C)	97	97	97	97	97	97	97
	Surface hardness (Shore D)	71	71	71	71	71	71	71
(Initial velocity of intermediate layer-encased sphere − initial velocity of core) × (weight of intermediate layer-encased sphere − weight of core): Miw		8	8	8	7	11	11	11
Surface hardness of intermediate layer − surface hardness of core (Shore C)		11	11	11	17	16	20	22
Surface hardness of intermediate layer − center hardness of core (Shore C)		39	39	39	43	40	43	45
Deflection of core − deflection of intermediate layer-encased sphere (mm)		0.93	0.93	0.93	0.99	0.74	0.77	0.81
Cover	Material	No. 3	No. 3	No. 3	No. 3	No. 3	No. 3	No. 3
	Thickness (mm)	0.84	0.84	0.84	0.84	0.82	0.81	0.82
	Material hardness (Shore C)	71	71	71	71	71	71	71
	Material hardness (Shore D)	50	50	50	50	50	50	50
Dimple	Specifications	II	III	IV	II	I	I	I
	Quantity	330	330	330	330	330	330	330
	Surface area coverage ratio: SR (%)	86	86	86	86	84	84	84
	Volume occupancy ratio: VR (%)	0.81	0.83	0.85	0.81	0.68	0.68	0.68
Ball	Outer diameter (mm)	42.69	42.69	42.69	42.75	42.68	42.68	42.68
	Weight (g)	45.55	45.54	45.52	45.57	45.53	45.55	45.54
	Deflection (mm)	2.95	2.96	2.98	3.29	2.83	3.07	3.26
	Initial velocity (m/s)	76.96	76.96	76.96	77.01	74.91	74.84	74.84
	Initial velocity/deflection	26.1	26.0	25.8	23.4	26.5	24.4	23.0
	Surface hardness (Shore C)	86	86	86	86	86	86	86
	Surface hardness (Shore D)	60	60	60	60	60	60	60
Weight of ball − weight of intermediate layer-encased sphere (g)		4.90	4.89	4.87	4.81	4.77	4.78	4.80
(Initial velocity of ball − initial velocity of intermediate layer-encased sphere) × (weight of ball − weight of intermediate layer-encased sphere): CViw		−3	−3	−3	−2	−2	−2	−2
Ciw + Miw + CViw		2,591	2,591	2,591	2,599	2,498	2,497	2,491
Surface hardness of intermediate layer − surface hardness of ball (Shore C)		11	11	11	11	11	11	11
Deflection of core − deflection of ball (mm)		1.18	1.17	1.15	1.23	0.95	0.97	1.07
Core diameter/ball diameter		0.892	0.892	0.892	0.891	0.891	0.891	0.890
Intermediate layer thickness − cover thickness (mm)		0.63	0.63	0.63	0.63	0.70	0.71	0.70

TABLE 7

		Comparative Example 4	5	6	7	8	9
Intermediate layer	Material	No. 1	No. 1	No. 2	No. 2	No. 2	—
	Thickness (mm)	1.47	1.47	1.17	1.17	1.21	—
	Weight (g)	6.82	6.82	5.54	5.54	5.71	—
	Material hardness (Shore C)	94	94	94	94	94	—
	Material hardness (Shore D)	65	65	67	67	67	—
Intermediate layer-encased sphere	Outer diameter (mm)	41.00	41.00	40.99	40.99	41.06	—
	Weight (g)	40.65	40.65	40.63	40.63	40.81	—
	Deflection (mm)	3.20	3.20	2.45	2.45	2.56	—
	Initial velocity (m/s)	77.54	77.54	77.50	77.50	73.38	—
	Initial velocity/deflection	24.2	24.2	31.6	31.6	28.7	—
	Surface hardness (Shore C)	97	97	97	97	97	—
	Surface hardness (Shore D)	71	71	71	71	71	—
(Initial velocity of intermediate layer-encased sphere − initial velocity of core) × (weight of intermediate layer-encased sphere − weight of core): Miw		8	8	4	4	4	—
Surface hardness of intermediate layer − surface hardness of core (Shore C)		11	11	10	10	16	—
Surface hardness of intermediate layer − center hardness of core (Shore C)		39	39	34	34	34	—
Deflection of core − deflection of intermediate layer-encased sphere (mm)		0.93	0.93	0.47	0.47	0.37	—
Cover	Material	No. 3	No. 3	No. 3	No. 3	No. 3	No. 4
	Thickness (mm)	0.84	0.84	0.85	0.85	0.81	1.46
	Material hardness (Shore C)	71	71	71	71	71	67
	Material hardness (Shore D)	50	50	50	50	50	47
Dimple	Specifications	I	V	I	IV	I	VI
	Quantity	330	330	330	330	330	338
	Surface area coverage ratio: SR (%)	84	85	84	86	84	75
	Volume occupancy ratio: VR (%)	0.68	0.93	0.68	0.85	0.68	0.77
Ball	Outer diameter (mm)	42.68	42.69	42.69	42.69	42.68	42.72
	Weight (g)	45.60	45.56	45.55	45.49	45.51	45.66
	Deflection (mm)	2.96	2.96	2.32	2.37	2.38	2.51
	Initial velocity (m/s)	76.91	76.94	77.17	76.99	73.06	73.36
	Initial velocity/deflection	26.0	26.0	33.3	32.5	30.7	29.2
	Surface hardness (Shore C)	86	86	87	87	87	79
	Surface hardness (Shore D)	60	60	61	61	61	53
Weight of ball − weight of intermediate layer-encased sphere (g)		4.95	4.91	4.92	4.86	4.70	8.67
(Initial velocity of ball − initial velocity of intermediate layer-encased sphere) × (weight of ball − weight of intermediate layer-encased sphere): CViw		−3	−3	−2	−2	−2	−2
Ciw + Miw + CViw		2,591	2,591	2,693	2,693	2,551	2,718
Surface hardness of intermediate layer − surface hardness of ball (Shore C)		11	11	10	10	10	—
Deflection of core − deflection of ball (mm)		1.17	1.17	0.60	0.55	0.55	0.12
Core diameter/ball diameter		0.892	0.892	0.905	0.905	0.905	0.932
Intermediate layer thickness − cover thickness (mm)		0.63	0.63	0.32	0.32	0.40	—

The flight (W#1 and I#6) and the controllability on approach shots of each golf ball are evaluated by the following methods. The results are shown in Table 8.

Evaluation of Flight (W#1, HS 54 m/s)

A driver is mounted on a golf swing robot, and a spin rate and a distance traveled (total) by a ball when struck at a head speed (HS) of 54 m/s are measured. The club used is a TOUR B XD-5 Driver/loft angle 9.5° (2017 model) manufactured by Bridgestone Sports Co., Ltd. and is evaluated according to the following rating criteria.

[Rating Criteria]

Good: Total compared with Comparative Example 6 is not more than −10.0 m, and at least −20.0 m.

Fair: Total compared with Comparative Example 6 is less than −20.0 m.

NG: Total compared with Comparative Example 6 is larger than −10.0 m.

Evaluation of Flight (W#1, HS 40 m/s)

A driver is mounted on a golf swing robot, and a spin rate and a distance traveled (total) by a ball when struck at a head speed (HS) of 40 m/s are measured. The club used is a JGR Driver/loft angle 9.5° (2016 model) manufactured by Bridgestone Sports Co., Ltd. and is evaluated according to the following rating criteria.

[Rating Criteria]

Good: Total compared with Comparative Example 6 is at least +5.0 m.

Fair: Total compared with Comparative Example 6 is at least 0.0 m and less than +5.0 m.

NG: Total compared with Comparative Example 6 is less than 0.0 m.

Evaluation of Flight (I#6, HS 42 m/s)

When a number six iron (I#6) is mounted on the golf swing robot and a ball is struck at an HS of 42 m/s, a spin rate and a distance traveled (total) are measured. The club used is a JGR Forged I#6 (2016 model) manufactured by Bridgestone Sports Co., Ltd. and is evaluated according to the following rating criteria.

[Rating Criteria]

Good: Total compared with Comparative Example 6 is at least +5.0 m.

Fair: Total compared with Comparative Example 6 is at least 0.0 m and less than +5.0 m.

NG: Total compared with Comparative Example 6 is less than 0.0 m.

Evaluation of Flight (I#6, HS 35 m/s)

When a number six iron (I#6) is mounted on the golf swing robot and a ball is struck at an HS of 35 m/s, a spin rate and a distance traveled (total) are measured. The club used is a JGR Forged I#6 (2016 model) manufactured by Bridgestone Sports Co., Ltd. and is evaluated according to the following rating criteria.

[Rating Criteria]

Good: Total compared with Comparative Example 6 is at least +5.0 m.

Fair: Total compared with Comparative Example 6 is at least 0.0 m and less than +5.0 m.

NG: Total compared with Comparative Example 6 is less than 0.0 m.

Evaluation of Spin Rate on Approach Shots

A judgment is made based on a spin rate when a sand wedge is mounted on the golf swing robot and a ball is struck at an HS of 15 m/s. Similarly, a spin rate immediately after the ball is struck is measured by a device for measuring initial conditions. The sand wedge used is a TOURSTAGE TW-03 (loft angle 57°) 2002 model manufactured by Bridgestone Sports Co., Ltd.

[Rating Criteria]

Good: Spin rate is at least 4,500 rpm

NG: Spin rate is less than 4,500 rpm

As shown in the results in Table 8, the golf balls of Comparative Examples 1 to 9 are inferior in the following respects to the golf balls according to the present invention (Examples).

In Comparative Example 1, the volume occupancy ratio VR of the dimple is smaller than 0.75%, the initial velocity of the ball is smaller than 76.5 m/s, and the value of Ciw+Miw+CViw is smaller than 2,500. As a result, each distance on shots with a driver (W#1, HS 40 m/s), a number six iron (I#6, HS 42 m/s), or a number six iron (I#6, HS 35 m/s) is inferior.

In Comparative Example 2, the volume occupancy ratio VR of the dimple is smaller than 0.75%, the initial velocity of the ball is smaller than 76.5 m/s, and the value of Ciw+Miw+CViw is smaller than 2,500. As a result, each distance on shots with a driver (W#1, HS 40 m/s), a number six iron (I#6, HS 42 m/s), or a number six iron (I#6, HS 35 m/s) is inferior.

In Comparative Example 3, the volume occupancy ratio VR of the dimple is smaller than 0.75%, the initial velocity of the ball is smaller than 76.5 m/s, and the value of Ciw+Miw+CViw is smaller than 2,500. As a result, each distance on shots with a driver (W#1, HS 40 m/s), a number six iron (I#6, HS 42 m/s), or a number six iron (I#6, HS 35 m/s) is inferior.

In Comparative Example 4, the volume occupancy ratio VR of the dimple is smaller than 0.75%. As a result, a distance on shots with a driver (W#1, HS 54 m/s) is inferior.

TABLE 8

			Example				Comparative Example								
			1	2	3	4	1	2	3	4	5	6	7	8	9
Flight	W#1 HS 54 m/s	Spin rate (rpm)	2,583	2,564	2,545	2,517	2,621	2,574	2,529	2,542	2,557	2,786	2,801	2,981	3,149
		Total (m)	270.5	269.6	268.8	268.5	269.6	271.0	266.3	276.1	256.0	281.5	271.5	269.3	259.8
		Total compared to Comp. Ex. 6	−11.0	−11.9	−12.7	−13.0	−11.9	−10.5	−15.2	−5.4	−25.5	0.0	−10.0	−12.2	−21.7
		Rating	Good	Good	Good	Good	Good	Good	Good	NG	Fair	NG	Good	Good	Fair
	W#1 HS 40 m/s	Spin rate (rpm)	2,900	2,900	2,900	2,862	3,009	2,906	2,850	2,912	2,904	3,154	3,177	3,372	3,629
		Total (m)	199.2	199.8	200.4	198.8	195.9	192.4	193.9	199.5	198.0	198.3	200.4	184.9	179.0
		Total compared to Comp. Ex. 6	0.9	1.5	2.1	0.5	−2.4	−5.9	−4.4	1.2	−0.3	0.0	2.1	−13.4	−19.3
		Rating	Fair	Fair	Fair	Fair	NG	NG	NG	Fair	NG	Fair	Fair	NG	NG
	I#6 HS 42 m/s	Spin rate (rpm)	5,020	5,030	5,039	4,857	5,213	5,088	4,944	4,948	5,002	5,721	5,780	6,249	6,354
		Total (m)	186.5	186.6	186.6	188.1	176.8	177.1	176.9	184.4	187.3	178.1	180.6	163.4	167.1
		Total compared to Comp. Ex. 6	8.4	8.5	8.5	10.0	−1.3	−1.0	−1.2	6.3	9.2	0.0	2.5	−14.7	−11.0
		Rating	Good	Good	Good	Good	NG	NG	NG	Good	Good	Fair	Fair	NG	NG
	I#6 HS 35 m/s	Spin rate (rpm)	4,763	4,785	4,807	4,622	5,051	4,805	4,751	4,724	4,764	5,487	5,448	5,881	6,067
		Total (m)	146.0	146.0	146.0	147.2	138.6	137.4	139.6	144.7	146.7	140.1	141.9	129.8	131.1
		Total compared to Comp. Ex. 6	5.9	5.9	5.9	7.1	−1.5	−2.7	−0.5	4.6	6.6	0.0	1.8	−10.3	−9.0
		Rating	Good	Good	Good	Good	NG	NG	NG	Fair	Good	Fair	Fair	NG	NG
Approach	SW HS 15 m/s	Spin rate (rpm)	5,075	5,107	5,139	4,967	5,088	5,116	5,079	5,087	5,100	5,128	5,161	5,162	5,079
		Rating	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good

In Comparative Example 5, the volume occupancy ratio VR of the dimple is larger than 0.89%. As a result, a distance on shots with a driver (W#1, HS 54 m/s) is excessively reduced, and a distance on shots with a driver (W#1, HS 40 m/s) is also reduced.

Comparative Example 6 is one embodiment of a tour ball currently used by professionals or advanced players. The volume occupancy ratio VR of the dimple is smaller than 0.75%, the deflection of the ball is smaller than 2.7 mm, and the value of Ciw+Miw+CViw is larger than 2,650. As a result, a distance on shots with a driver (W#1, HS 54 m/s) is too large, and each distance on shots with a driver (W#1, HS 40 m/s), a number six iron (I#6, HS 42 m/s), and a number six iron (I#6, HS 35 m/s) is inferior to those in the Examples.

In Comparative Example 7, the deflection of the ball is smaller than 2.7 mm, and the value of Ciw+Miw+CViw is larger than 2,650. As a result, each distance on shots with a driver (W#1, HS 40 m/s), a number six iron (I#6, HS 42 m/s), or a number six iron (I#6, HS 35 m/s) is inferior to those in the Examples.

In Comparative Example 8, the volume occupancy ratio VR of the dimple is smaller than 0.75%, the deflection of the ball is smaller than 2.7 mm, and the initial velocity of the ball is smaller than 76.5 m/s. As a result, each distance on shots with a driver (W#1, HS 40 m/s), a number six iron (I#6, HS 42 m/s), or a number six iron (I#6, HS 35 m/s) is inferior.

Comparative Example 9 corresponds to a practice ball having a two-piece structure for a driving range, in which the deflection of the ball is smaller than 2.7 mm, the initial velocity of the ball is smaller than 76.5 m/s, and the value of Ciw+Miw+CViw is larger than 2,650. As a result, a distance on shots with a driver (W#1, HS 54 m/s) is excessively reduced, and each distance on shots with a driver (W#1, HS 40 m/s), a number six iron (I#6, HS 42 m/s), and a number six iron (I#6, HS 35 m/s) is also reduced.

Japanese Patent Application No. 2022-179044 is incorporated herein by reference. Although some preferred embodiments have been described, many modifications and variations may be made thereto in light of the above teachings. It is therefore to be understood that the invention may be practiced otherwise than as specifically described without departing from the scope of the appended claims.

The invention claimed is:

1. A multi-piece solid golf ball comprising a core, an intermediate layer, and a cover, wherein a large number of dimples are formed on an outer surface of the cover, and a relationship between a surface hardness of an intermediate layer-encased sphere and a surface hardness of the ball satisfies the following condition:

$$\text{(surface hardness of ball)} < \text{(surface hardness of intermediate layer-encased sphere)}$$

[where the surface hardnesses mean Shore C hardnesses], and

when an initial velocity of the ball is 76.5 m/s to 77.724 m/s and a deflection is at least 2.7 mm when the ball is compressed under a final load of 1,275 N (130 kgf) from an initial load of 98 N (10 kgf), and a value of (initial velocity of core×weight of core) is denoted by Ciw, a value of [(initial velocity of intermediate layer-encased sphere−initial velocity of core)×(weight of intermediate layer-encased sphere−weight of core)] is denoted by Miw, and a value of [(initial velocity of ball−initial velocity of intermediate layer-encased sphere)×(weight of ball−weight of intermediate layer-encased sphere)] is denoted by CViw, the following condition is satisfied:

$$2{,}500 \le Ciw + Miw + CViw \le 2{,}650, \text{ and}$$

a volume occupancy ratio VR of the dimples are from 0.75 to 0.89%, and

wherein when each sphere of the core, intermediate layer-encased sphere, and the ball is compressed under a final load of 1,275 N (130 kgf) from an initial load of 98 N (10 kgf) and deflections (mm) are denoted by C (mm), M (mm), and B (mm) respectively, the following two conditions are satisfied:

$$1.00 \le C - B \le 1.50$$

$$0.65 \le C - M \le 1.15.$$

2. The multi-piece solid golf ball according to claim **1**, wherein when an initial velocity of the core is denoted by Vc (m/s), and a deflection is denoted by C (mm) when the core is compressed under a final load of 1,275 N (130 kgf) from an initial load of 98 N (10 kgf), the following condition is satisfied:

$$15 \le Vc/C \le 25.$$

3. The multi-piece solid golf ball according to claim **1**, wherein a relationship between a surface hardness of the core and the surface hardness of the intermediate layer-encased sphere satisfies the following condition:

$$\text{(surface hardness of ball)} \ge \text{(surface hardness of intermediate layer-encased sphere)}$$

[where the surface hardnesses mean Shore C hardnesses].

4. The multi-piece solid golf ball according to claim **1**, wherein when the core is compressed under a final load of 1,275 N (130 kgf) from an initial load of 98 N (10 kgf) and a deflection (mm) is denoted by C (mm), the following condition is satisfied:

$$400 \le Ciw/C \le 850.$$

5. A multi-piece solid golf ball comprising a core, an intermediate layer, and a cover, wherein a large number of dimples are formed on an outer surface of the cover, and a relationship between a surface hardness of an intermediate layer-encased sphere and a surface hardness of the ball satisfies the following condition:

$$\text{(surface hardness of ball)} < \text{(surface hardness of intermediate layer-encased sphere)}$$

[where the surface hardnesses mean Shore C hardnesses], and

when an initial velocity of the ball is 76.5 m/s to 77.724 m/s and a deflection is at least 2.7 mm when the ball is compressed under a final load of 1,275 N (130 kgf) from an initial load of 98 N (10 kgf), and a value of (initial velocity of core×weight of core) is denoted by Ciw, a value of [(initial velocity of intermediate layer-encased sphere−initial velocity of core)×(weight of intermediate layer-encased sphere−weight of core)] is denoted by Miw, and a value of [(initial velocity of ball−initial velocity of intermediate layer-encased sphere)×(weight of ball−weight of intermediate layer-encased sphere)] is denoted by CViw, the following condition is satisfied:

$$2{,}500 \le Ciw + Miw + CViw \le 2{,}650, \text{ and}$$

a volume occupancy ratio VR of the dimples are from 0.75 to 0.89%, and wherein the core has a hardness profile in which, letting the Shore C hardness at a core center be Cc, the Shore C hardness at a midpoint M between the core center and a core surface be Cm, the Shore C hardnesses at positions 2 mm, 4 mm, and 6 mm inward from the midpoint M be Cm-2, Cm-4, and Cm-6 respectively, the Shore C hardnesses at positions 2 mm, 4 mm, and 6 mm outward from the midpoint M be Cm+2, Cm+4, and Cm+6 respectively, and the Shore C hardness at the core surface be Cs, and defining surface areas A to F as follows:

surface area A: ½×2×(Cm−4−Cm−6)

surface area B: ½×2×(Cm−2−Cm−4)

surface area C: ½×2×(Cm−Cm−2)

surface area D: ½×2×(Cm+2−Cm)

surface area E: ½×2×(Cm+4−Cm+2)

surface area F: ½×2×(Cm+6−Cm+4)

the following condition is satisfied:

$$\{(\text{surface area } D+\text{surface area } E)-(\text{surface area } A+\text{surface area } B)\}\geq 2.0.$$

6. The multi-piece solid golf ball according to claim **5**, wherein the core has a hardness profile in which the following condition is satisfied:

$$(Cs-Cc)\geq 22.$$

7. The multi-piece solid golf ball according to claim **5**, wherein the core has a hardness profile in which the following condition is satisfied:

$$(Cs-Cc)/(Cm-Cc)\geq 3.0.$$

8. The multi-piece solid golf ball according to claim **5**, wherein the core has a hardness profile in which the following condition is satisfied:

$$\text{surface area } E>\text{surface area } D>\text{surface area } C.$$

* * * * *