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

(57) **ABSTRACT**

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The invention provides a multi-piece solid golf ball having a solid core encased by a cover of one, two or more layers, the solid core including a spherical first layer, a second layer encasing the first layer and a third layer encasing the second layer. The first layer has a diameter of from 3 to 24 mm, and the third layer is formed of a rubber composition composed primarily of polybutadiene rubber. The ball has specific relationships between the cross-sectional hardness at the core center on a cut face when the solid core has been cut in half and the respective hardnesses of the first layer 1 mm inside an interface between the first layer and the second layer, the second layer 1 mm outside the interface between the first layer and the second layer, the second layer 1 mm inside an interface between the second layer and the third layer, the third layer 1 mm outside the interface between the second layer and the third layer, and the surface of the third layer. Such a golf ball has an increased initial velocity, particularly when struck in a high head speed range, enabling an increased distance to be achieved, in addition to which the ball is able to obtain a good feel on impact.

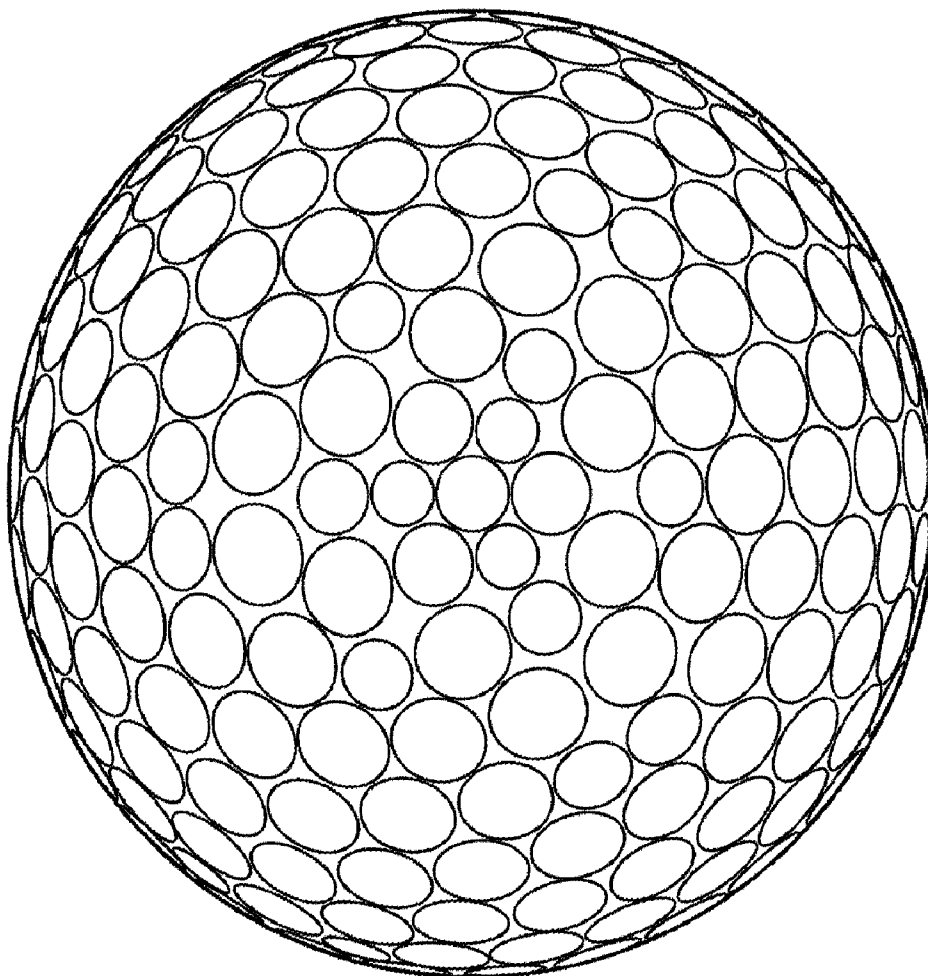
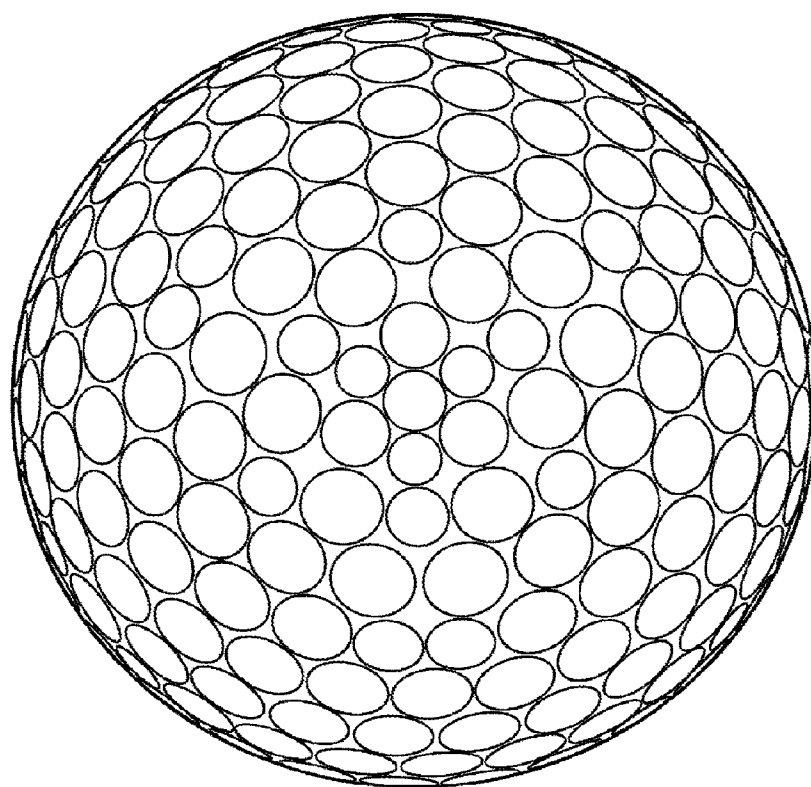


FIG.1



MULTI-PIECE SOLID GOLF BALL

BACKGROUND OF THE INVENTION

[0001] The present invention relates to a multi-piece solid golf ball having a solid core with a multilayer construction that includes a spherical first layer, a second layer encasing the first layer, and a third layer encasing the second layer, and having a cover of one, two or more layers encasing the core. More specifically, the invention relates to a multi-piece solid golf ball having an excellent flight performance and feel.

[0002] To increase the distance traveled by a golf ball and also improve the feel of the ball when played, innovations have hitherto been made which involve designing the ball structure as a multilayer structure. Following such innovations, various multi-piece golf balls have been proposed in which not only the cover but the core as well has been given a structure of two or more layers for the purpose of lowering the spin rate, increasing the initial velocity and achieving further improvements in head speed (HS) dependence and feel on impact.

[0003] For example, U.S. Pat. Nos. 6,290,612, 7,086,969, 7,160,208, 7,175,542 and 7,367,901 disclose golf balls having a solid core with a two-layer structure and having a cover. In addition, U.S. Pat. Nos. 7,510,487, 6,569,036, 6,626,770, 5,743,816 and 7,708,656 disclose golf balls having a solid core with a three-layer structure. However, all of these conventional golf balls lack a sufficient initial velocity when hit with a driver (W#1) or do not have a good feel on impact, and so further improvement has been desired.

SUMMARY OF THE INVENTION

[0004] It is therefore an object of the present invention to provide a multi-piece solid golf ball which has a core with a multilayer construction, has an improved initial velocity particularly when struck in a high head speed range, and is able to increase the distance traveled by the ball on shots with a driver (W#1).

[0005] As a result of extensive investigations aimed at achieving the above objects, the inventor has discovered that, in a golf ball having a solid core encased by a cover, which solid core has a multilayer construction composed of a spherical first layer, a second layer encasing the first layer and a third layer encasing the second layer, by setting the cross-sectional hardness of the core so as to gradually decrease from the first layer toward the third layer and thus optimizing the hardness relationship among the core layers, the initial velocity of the ball increases, particularly when struck in the high head speed range, enabling the flight performance on shots with a driver (W#1) to be improved, in addition to which a good feel on impact can be obtained.

[0006] Accordingly, the invention provides the following multi-piece solid golf balls.

[0007] [1] A multi-piece solid golf ball comprising a solid core encased by a cover of one, two or more layers, the solid core comprising a spherical first layer, a second layer encasing the first layer and a third layer encasing the second layer, wherein the first layer has a diameter of from 3 to 24 mm; the third layer is formed of a rubber composition composed primarily of polybutadiene rubber; and, letting (a) represent the cross-sectional hardness at a center of the core on a cut face when the solid core has been cut in half, (b) represent the cross-sectional hardness, expressed as the JIS-C hardness, of the first layer 1 mm inside an interface

between the first layer and the second layer, (c) represent the cross-sectional hardness, expressed as the JIS-C hardness, of the second layer 1 mm outside the interface between the first layer and the second layer, (d) represent the cross-sectional hardness, expressed as the JIS-C hardness, of the second layer 1 mm inside an interface between the second layer and the third layer, (e) represent the cross-sectional hardness, expressed as the JIS-C hardness, of the third layer 1 mm outside the interface between the second layer and the third layer, and (f) represent the surface hardness, expressed as the JIS-C hardness, of the third layer:

- [0008] the value (b)–(c) is in a range of from 0 to 40,
- [0009] the value (e)–(d) is in a range of from –40 to 0, and
- [0010] the value (a)+(b)+(c)+(d)+(e)+(f) is in a range of from 430 to 490.
- [0011] [2] The multi-piece solid golf ball of [1], wherein the value (f)–(a) in the solid core is in a range of from –10 to 10.
- [0012] [3] The multi-piece solid golf ball of [1], wherein the first layer is formed of a rubber composition composed primarily of polybutadiene rubber.
- [0013] [4] The multi-piece solid golf ball of [1], wherein the cross-sectional hardness (a) of the solid core, expressed as the JIS-C hardness, is in a range of from 70 to 95.
- [0014] [5] The multi-piece solid golf ball of [1], wherein the second layer is formed of a rubber composition composed primarily of polybutadiene rubber.
- [0015] [6] The multi-piece solid golf ball of [1], wherein a sphere composed of the first layer encased by the second layer (second layer-covered sphere) has a diameter of from 20 to 33 mm.
- [0016] [7] The multi-piece solid golf ball of [1], wherein the diameter ratio between the first layer and the second layer-covered sphere (first layer diameter/second layer-covered sphere diameter) is from 0.20 to 0.50.
- [0017] [8] The multi-piece solid golf ball of [1], wherein the volume ratio between the second layer and the solid core (second layer volume/solid core volume) is from 0.10 to 0.50.
- [0018] [9] The multi-piece solid golf ball of [1], wherein the ratio between the deflection of the second layer-covered sphere when compressed under a final load of 1,275 N (130 kgf) from an initial load state of 98 N (10 kgf) to the deflection of the solid core when compressed under a final load of 1,275 N (130 kgf) from an initial load state of 98 N (10 kgf) (second layer-covered sphere deflection/solid core deflection) is from 0.90 to 1.20.
- [0019] [10] The multi-piece solid golf ball of [1], wherein the ratio between the deflection of the solid core when compressed under a final load of 1,275 N (130 kgf) from an initial load state of 98 N (10 kgf) to the deflection of the ball when compressed under a final load of 1,275 N (130 kgf) from an initial load state of 98 N (10 kgf) (solid core deflection/ball deflection) is from 1.00 to 1.30.
- [0020] [11] The multi-piece solid golf ball of [1], wherein the ratio between the deflection of the ball when compressed under a final load of 5,880 N (600 kgf) from an initial load state of 98 N (10 kgf) and the deflection of the ball when compressed under a final load of 1,275 N (130

kgf) from an initial load state of 98 N (10 kgf) (600 kgf deflection/130 kgf deflection) is from 3.30 to 3.70.

BRIEF DESCRIPTION OF THE DIAGRAMS

[0021] FIG. 1 is a plan view showing the dimple pattern used on balls in the examples of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0022] The invention is described more fully below.

[0023] The multi-piece solid golf ball of the invention, although not shown in an accompanying diagram, is composed of a solid core having a multilayer structure which includes a spherical first layer, a second layer encased by the first layer, and a third layer encased by the second layer, which solid core is encased by a cover of one, two or more layers.

[0024] The first layer is the layer positioned on the innermost side in the golf ball of the invention, and is spherical. Materials capable of forming this first layer are not subject to any particular limitation, although the first layer may be formed using a rubber composition composed primarily of polybutadiene or a resin composition composed primarily of a thermoplastic resin.

[0025] The first layer is described first for cases in which it is formed using a rubber composition.

[0026] In the invention, in cases where the first layer is formed using a rubber composition, preferred use may be made of a rubber composition in which polybutadiene is used as the base rubber.

[0027] Here, the polybutadiene is not subject to any particular limitation, although the use of a polybutadiene having a cis-1,4 bond content of at least 60%, preferably at least 80%, more preferably at least 90%, and most preferably at least 95%, is recommended.

[0028] It is recommended that the polybutadiene, although not subject to any particular limitation, have a Mooney viscosity (ML_{1+1} (100° C.)) of at least 30, preferably at least 35, more preferably at least 40, even more preferably at least 50, and most preferably at least 52. It is recommended that the upper limit, although not subject to any particular limitation, be not more than 100, preferably not more than 80, more preferably not more than 70, and even more preferably not more than 60.

[0029] The term “Mooney viscosity” used herein refers to an industrial indicator of viscosity (JIS K6300) as measured with a Mooney viscometer, which is a type of rotary plastometer. This value is represented by the unit symbol ML_{1+4} (100° C.), wherein “M” stands for Mooney viscosity, “L” stands for large rotor (L-type), and “1+4” stands for a pre-heating time of 1 minute and a rotor rotation time of 4 minutes. The “100° C.” indicates that measurement was carried out at a temperature of 100° C.

[0030] In addition, the polybutadiene has a molecular weight distribution Mw/Mn (Mw: weight-average molecular weight; Mn: number-average molecular weight) which, although not subject to any particular limitation, is at least 2.0, preferably at least 2.2, more preferably at least 2.4, and even more preferably at least 2.6. The upper limit, although not subject to any particular limitation, is typically not more than 6.0, preferably not more than 5.0, more preferably not more than 4.0, and even more preferably not more than 3.4. If Mw/Mn is too small, the workability may decrease; if Mw/Mn is too large, the resilience may decrease.

[0031] The polybutadiene used may be one which has been synthesized using a nickel catalyst, a cobalt catalyst, a Group VIII metal catalyst or a rare-earth catalyst. In this invention, it is preferable to use a polybutadiene synthesized with, in particular, a nickel catalyst or a rare-earth catalyst. Also, where necessary, an organoaluminum compound, an alumoxane, a halogen-bearing compound, a Lewis base and the like may be used in combination with these catalysts. In this invention, it is preferable to use, as the various above-mentioned compounds, those mentioned in JP-A 11-35633.

[0032] Of the above rare-earth catalysts, the use of a neodymium catalyst that employs a neodymium compound, which is a lanthanide series rare-earth compound, is especially recommended because it enables a polybutadiene rubber having a high cis-1,4 bond content and a low 1,2-vinyl bond content to be obtained at an excellent polymerization activity.

[0033] The polymerization of butadiene in the presence of a rare-earth catalyst may be carried out by bulk polymerization or vapor phase polymerization, either with or without the use of a solvent, and at a polymerization temperature in a range of generally from -30 to 150° C., and preferably from 10 to 100° C.

[0034] The above polybutadiene may be one obtained by polymerization using the above-described rare-earth catalyst, followed by the reaction of a terminal modifier with active end groups on the polymer.

[0035] Specific examples of the terminal modifier and methods for their reaction are described in, for example, JP-A 11-35633, JP-A 7-268132 and JP-A 2002-293996.

[0036] It is recommended that the amount of the above polybutadiene included in the base rubber, although not subject to any particular limitation, be at least 60 wt %, preferably at least 70 wt %, more preferably at least 80 wt %, and even more preferably at least 90 wt %, and that the upper limit be 100 wt % or less, preferably 98 wt % or less, and more preferably 95 wt % or less. If the content is inadequate, it may be difficult to obtain golf balls conferred with a good rebound.

[0037] Rubbers other than the above polybutadiene may also be used together and included, insofar as the objects of the invention are attainable. Illustrative examples include polybutadiene rubbers (BR), styrene-butadiene rubbers (SBR), natural rubbers, polyisoprene rubbers and ethylene-propylene-diene rubbers (EPDM). These may be used singly or a combination of two or more types.

[0038] The first layer is formed of a rubber composition obtained by blending additives, such as an unsaturated carboxylic acid or a metal salt thereof, an organosulfur compound, an inorganic filler and an antioxidant, in given amounts with the above-described base rubber.

[0039] Illustrative examples of the unsaturated carboxylic acid include acrylic acid, methacrylic acid, maleic acid and fumaric acid. The use of acrylic acid or methacrylic acid is especially preferred.

[0040] Illustrative examples of metal salts of unsaturated carboxylic acids include zinc salts and magnesium salts of unsaturated fatty acids, such as zinc methacrylate and zinc acrylate. The use of zinc acrylate is especially preferred.

[0041] The amount of the unsaturated carboxylic acid and/or a metal salt thereof included in the rubber composition, although not subject to any particular limitation, may be set to preferably at least 10 parts by weight, and more preferably at least 15 parts by weight, per 100 parts by weight of the base rubber. It is recommended that the upper limit, although not subject to any particular limitation, be set to not more than 50

parts by weight. If the amount included is too high, the ball may become too hard, resulting in an unpleasant feel on impact. On the other hand, if the amount is too low, the rebound may decrease.

[0042] An organosulfur compound may optionally be included. The organosulfur compound can be advantageously used to impart an excellent rebound. Thiophenols, thionaphthols, halogenated thiophenols, and metal salts thereof are recommended for this purpose. Illustrative examples include pentachlorothiophenol, pentafluorothiophenol, pentabromothiophenol, p-chlorothiophenol, and the zinc salt of pentachlorothiophenol; and diphenylpolysulfides, dibenzylpolysulfides, dibenzoylpolysulfides, dibenzothiazoylpolysulfides and dithiobenzoylpolysulfides having 2 to 4 sulfurs. Diphenyldisulfide and the zinc salt of pentachlorothiophenol are especially preferred.

[0043] The amount of the organosulfur compound included can be set to more than 0, and may be set to preferably at least 0.1 part by weight, more preferably at least 0.2 part by weight, and even more preferably at least 0.4 part by weight, per 100 parts by weight of the base rubber. The upper limit in the amount included, although not subject to any particular limitation, may be set to preferably not more than 5 parts by weight, more preferably not more than 4 parts by weight, even more preferably not more than 3 parts by weight, and most preferably not more than 2 parts by weight. Including too much organosulfur compound may excessively lower the hardness, whereas including too little is unlikely to improve the rebound.

[0044] The inorganic filler is exemplified by zinc oxide, barium sulfate and calcium carbonate. The amount of the inorganic filler included is not subject to any particular limitation, although it may be set to preferably at least 5 parts by weight, more preferably at least 6 parts by weight, even more preferably at least 7 parts by weight, and most preferably at least 8 parts by weight, per 100 parts by weight of the base rubber. The upper limit in the amount included may be set to preferably not more than 80 parts by weight, more preferably not more than 60 parts by weight, even more preferably not more than 40 parts by weight, and most preferably not more than 20 parts by weight. Too much or too little inorganic filler may make it impossible to achieve a suitable weight and a good rebound.

[0045] To increase the hardness profile, the organic peroxide used is preferably one having a relatively short half-life. Specifically, use is made of an organic peroxide which has a half-life at 155° C. (at) of preferably at least 5 seconds, more preferably at least 10 seconds, and even more preferably at least 15 seconds. Moreover, the organic peroxide used has a half-life at 155° C. (at) of preferably not more than 120 seconds, more preferably not more than 90 seconds, and even more preferably not more than 60 seconds. Examples of organic peroxides which satisfy these conditions include 1,1-bis(t-hexylperoxy)cyclohexane (trade name, Perhexa HC), 1,1-bis(t-hexylperoxy)-3,3,5-trimethylcyclohexane (trade name, Perhexa TMH), 1,1-bis(t-butylperoxy)-3,3,5-trimethylcyclohexane (trade name, Perhexa 3M) and 1-bis(t-butylperoxy)-cyclohexane (trade name, Perhexa C). These are all available from NOF Corporation.

[0046] The organic peroxide is included in an amount which, although not subject to any particular limitation, is preferably at least 0.3 part by weight, more preferably at least 0.4 part by weight, and even more preferably at least 0.5 part by weight, per 100 parts by weight of the base rubber. The

upper limit in the amount of organic peroxide is not subject to any particular limitation, although it is recommended that it be preferably not more than 4 parts by weight, more preferably not more than 3 parts by weight, even more preferably not more than 2 parts by weight, and most preferably not more than 1.5 parts by weight. In this invention, to achieve a suitable rebound and durability, it is preferable for the amount of organic peroxide to be set in the above-indicated range. If the amount of organic peroxide is too high, the rebound and durability may decline. On the other hand, if the amount of organic peroxide is too low, the time required for crosslinking may increase, possibly resulting in a large decline in productivity and also a large decline in compression.

[0047] If necessary, an antioxidant may be included in the above rubber composition. Illustrative examples of the antioxidant include commercial products such as Nocrac NS-6 and Nocrac NS-30 (both available from Ouchi Shinko Chemical Industry Co., Ltd.), and Yoshinox 425 (Yoshitomi Pharmaceutical Industries, Ltd.).

[0048] The amount of antioxidant included can be set to more than 0, and may be set to preferably at least 0.03 part by weight, and more preferably at least 0.05 part by weight, per 100 parts by weight of the base rubber. The upper limit in the amount of antioxidant, although not subject to any particular limitation, may be set to preferably not more than 0.4 part by weight, more preferably not more than 0.3 part by weight, and even more preferably not more than 0.2 part by weight. In this invention, it is recommended that the amount of the antioxidant be set within the above range so as to enable a suitable rebound and durability to be achieved.

[0049] Sulfur may also be added if necessary. Such sulfur is exemplified by the product manufactured by Tsurumi Chemical Industry Co., Ltd. under the trade name Sulfur Z. The amount of sulfur included can be set to more than 0, and may be set to preferably at least 0.005 part by weight, and more preferably at least 0.01 part by weight, per 100 parts by weight of the base rubber. The upper limit in the amount of sulfur, although not subject to any particular limitation, may be set to preferably not more than 0.5 part by weight, more preferably not more than 0.4 part by weight, and even more preferably not more than 0.1 part by weight. By adding sulfur, the hardness profile of the core can be increased. However, adding too much sulfur may result in undesirable effects during hot molding, such as explosion of the rubber composition, or may considerably lower the rebound.

[0050] When a rubber composition is used to form the first layer (hot-molded material), to obtain the subsequently described cross-sectional hardness, the foregoing rubber composition is suitably selected and fabrication may be carried out by vulcanization and curing according to a method similar to that used for conventional golf ball rubber compositions. Suitable vulcanization conditions include, for example, a vulcanization temperature of between 100° C. and 200° C., and a vulcanization time of from 10 to 40 minutes. To obtain the desired rubber crosslinked body for use as the core in the present invention, the vulcanizing temperature is preferably at least 150° C., and especially at least 155° C., but preferably not above 200° C., more preferably not above 190° C., even more preferably not above 180° C., and most preferably not above 170° C.

[0051] Next, when the first layer is formed using a thermoplastic resin, although not subject to any particular limitation, use may be made of thermoplastic resins such as nylons, polyarylates, ionomer resins, polypropylene resins, polyure-

thane-type thermoplastic elastomers and polyester-type thermoplastic elastomers. Commercial products which may be suitably used as these resins include Surlyn AD8512 (an ionomer resin available from E.I. DuPont de Nemours and Co.), Himilan 1706 and Himilan 1707 (both ionomer resins available from DuPont-Mitsui Polychemicals Co., Ltd.), Rilsan BMNO (a nylon resin available from Arkema) and U-Polymer U-8000 (a polyarylate resin available from Unika, Ltd.).

[0052] In the present invention, of the above thermoplastic resins, it is especially desirable to use an ionomer resin, an unneutralized form thereof, or a highly neutralized ionomer resin. The ionomer resin or unneutralized form thereof is preferably a resin composition in which the following resin components A-I and A-II serve as the base resins:

[0053] (A-I) an olefin-unsaturated carboxylic acid-unsaturated carboxylic acid ester ternary random copolymer and/or a metal salt thereof; and

[0054] (A-II) an olefin-unsaturated carboxylic acid binary random copolymer and/or a metal salt thereof.

[0055] This resin composition is described below.

[0056] The olefin-unsaturated carboxylic acid-unsaturated acid ester ternary random copolymer and/or metal salt thereof serving as component A-I has a weight-average molecular weight (Mw) of preferably at least 100,000, more preferably at least 110,000, and even more preferably at least 120,000. The upper limit is preferably not more than 200,000, more preferably not more than 190,000, and even more preferably not more than 180,000. The weight-average molecular weight (Mw) to number-average molecular weight (Mn) ratio of the copolymer is preferably at least 3, and more preferably at least 4.5, with the upper limit being preferably not more than 7, and more preferably not more than 6.5.

[0057] The olefin-unsaturated carboxylic acid binary random copolymer and/or metal salt thereof serving as component A-II has a weight-average molecular weight (Mw) of preferably at least 150,000, more preferably at least 160,000, and even more preferably at least 170,000. The upper limit is preferably not more than 200,000, more preferably not more than 190,000, and even more preferably not more than 180,000. The weight-average molecular weight (Mw) to number-average molecular weight (Mn) ratio is preferably at least 3, and more preferably at least 4.5, with the upper limit being preferably not more than 7, and more preferably not more than 6.5.

[0058] Here, the weight-average molecular weight (Mw) and number-average molecular weight (Mn) are values calculated relative to polystyrene in gel permeation chromatography (GPC). A word of explanation is needed here concerning GPC molecular weight measurement. It is not possible to directly take GPC measurements for binary copolymers and ternary copolymers because these molecules are adsorbed to the GPC column owing to the unsaturated carboxylic acid groups within the molecule. Instead, the unsaturated carboxylic acid groups are generally converted to esters, following which GPC measurement is carried out and the polystyrene-equivalent average molecular weights Mw and Mn are calculated.

[0059] The olefins in components A-I and A-II are exemplified by olefins in which the number of carbons is at least 2, but not more than 8, and preferably not more than 6. Illustrative examples of such olefins include ethylene, propylene, butene, pentene, hexene, heptene and octene. Ethylene is especially preferred.

[0060] Illustrative examples of the unsaturated carboxylic acid include acrylic acid, methacrylic acid, maleic acid and fumaric acid. Acrylic acid and methacrylic acid are especially preferred.

[0061] The unsaturated carboxylic acid ester included in component A-I is preferably a lower alkyl ester of the above-mentioned unsaturated carboxylic acid. Illustrative examples include methyl methacrylate, ethyl methacrylate, propyl methacrylate, butyl methacrylate, methyl acrylate, ethyl acrylate, propyl acrylate and butyl acrylate. Butyl acrylate (n-butyl acrylate, i-butyl acrylate) is especially preferred.

[0062] The random copolymer used as component A-I or component A-II may be obtained by random copolymerization of the above ingredients in accordance with a known method. Here, the content of unsaturated carboxylic acid (acid content) included in the random copolymer, although not subject to any particular limitation, is preferably at least 2 wt %, more preferably at least 6 wt %, and even more preferably at least 8 wt %. It is recommended that the upper limit, although not subject to any particular limitation, be not more than 25 wt %, more preferably not more than 20 wt %, and even more preferably not more than 15 wt %. At a low acid content, the rebound may decrease, whereas at a high acid content, the processability of the material may decrease.

[0063] It is essential to set the relative proportions in the contents of component A-I and component A-II, expressed as the weight ratio therebetween, at generally from 100:0 to 0:100, preferably from 100:0 to 25:75, more preferably from 100:0 to 50:50, even more preferably from 100:0 to 75:25, and most preferably 100:0. If the content of component A-II is too low, moldings of the material may have a decreased resilience.

[0064] The metal salts of the copolymer in above components A-I and A-II may be obtained by partially neutralizing the acid groups in the random copolymers of components A-I and A-II with metal ions. Here, specific examples of the metal ions which neutralize the acid groups include Na⁺, K⁺, Li⁺, Zn²⁺, Cu²⁺, Mg²⁺, Ca²⁺, Co²⁺, Ni²⁺ and Pb²⁺. In the invention, of these, preferred use may be made of Na⁺, Li⁺, Zn²⁺, Mg²⁺ and Ca²⁺; Zn²⁺ and Mg²⁺ are especially preferred.

[0065] In cases where metal neutralization products of the above copolymers are used as components A-I and A-II, i.e., in cases where an ionomer resin is used, the type of metal neutralization product and the degree of neutralization are not subject to any particular limitation. Specific examples include 60 mol % Zn (degree of neutralization with zinc) ethylene-acrylic acid copolymers, 40 mol % Mg (degree of neutralization with magnesium) ethylene-acrylic acid copolymers, 40 mol % Mg (degree of neutralization with magnesium) ethylene-methacrylic acid-isobutylene acrylate terpolymers, and 60 mol % Zn (degree of neutralization with zinc) ethylene-methacrylic acid-isobutylene acrylate terpolymers.

[0066] Illustrative examples of the olefin-unsaturated carboxylic acid-unsaturated carboxylic acid ester ternary random copolymer of component A-I include those available under the trade names Nucrel AN4318, Nucrel AN4319, Nucrel AN4311, Nucrel N035C and Nucrel N0200H (DuPont-Mitsui Polychemicals Co., Ltd.). Illustrative examples of the metal salts of olefin-unsaturated carboxylic acid-unsaturated carboxylic acid ester ternary random copolymers include those available under the trade names Himilan AM7316, Himilan AM7331, Himilan 1855 and Himilan 1856 (DuPont-Mitsui Polychemicals Co., Ltd.), and those avail-

able under the trade names Surlyn 6320 and Surlyn 8120 (E.I. DuPont de Nemours and Co., Ltd.).

[0067] Illustrative examples of the olefin-unsaturated carboxylic acid binary random copolymer of component A-II include those available under the trade names Nucrel 1560, Nucrel 1525 and Nucrel 1035 (DuPont-Mitsui Polychemicals Co., Ltd.). Illustrative examples of the metal salts of olefin-unsaturated carboxylic acid binary random copolymers include those available under the trade names Himilan 1605, Himilan 1601, Himilan 1557, Himilan 1705 and Himilan 1706 (DuPont-Mitsui Polychemicals Co., Ltd.); those available under the trade names Surlyn 7930 and Surlyn 7920 (E.I. DuPont de Nemours and Co., Ltd.); and those available under the trade names Escor 5100 and Escor 5200 (ExxonMobil Chemical).

[0068] In addition, to achieve a good rebound, use may be made of a highly neutralized ionomer resin in which the degree of neutralization has been increased by mixing the subsequently described (B) fatty acid or derivative thereof having a molecular weight of at least 280 but not more than 1,500 and (C) a basic inorganic metal compound with above components A-I and A-II under applied heat.

[0069] Component B is a fatty acid or fatty acid derivative having a molecular weight of at least 280 but not more than 1,500 whose purpose is to increase the flow properties of the heated mixture. Compared with the thermoplastic resins of component A, it has a much smaller molecular weight and helps to significantly decrease the melt viscosity of the mixture. Also, because the fatty acid (or fatty acid derivative) of component B has a molecular weight of at least 280 but not more than 1,500 and has a high content of acid groups (or derivative moieties thereof), its addition results in little if any loss of resilience.

[0070] The fatty acid or fatty acid derivative serving as component B may be an unsaturated fatty acid (or fatty acid derivative) having a double bond or triple bond in the alkyl moiety, or it may be a saturated fatty acid (or fatty acid derivative) in which all the bonds in the alkyl moiety are single bonds. It is recommended that the number of carbons on the molecule be preferably at least 18, but preferably not more than 80, and more preferably not more than 40. Too few carbons may result in a poor heat resistance, and may also set the acid group content so high as to cause the acid groups to interact with acid groups present on the base resin, as a result of which the desired flow properties may not be achieved. On the other hand, too many carbons increases the molecular weight, which may lower the flow properties. In either case, the material may become difficult to use.

[0071] Specific examples of fatty acids that may be used as component B include stearic acid, 12-hydroxystearic acid, behenic acid, oleic acid, linoleic acid, linolenic acid, arachidic acid and lignoceric acid. Of these, preferred use may be made of stearic acid, arachidic acid, behenic acid, lignoceric acid and oleic acid.

[0072] The fatty acid derivative is exemplified by derivatives in which the proton on the acid group of the fatty acid has been substituted. Exemplary fatty acid derivatives of this type include metallic soaps in which the proton has been substituted with a metal ion. Metal ions that may be used in such metallic soaps include Li⁺, Ca⁺⁺, Mg⁺⁺, Zn⁺⁺, Mn⁺⁺, Al⁺⁺⁺, Ni⁺⁺, Fe⁺⁺, Fe⁺⁺⁺, Cu⁺⁺, Sn⁺⁺, Pb⁺⁺ and Co⁺⁺. Of these, Ca⁺⁺, Mg⁺⁺ and Zn⁺⁺ are especially preferred.

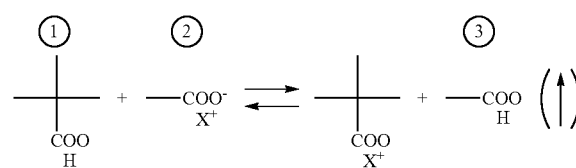
[0073] Specific examples of fatty acid derivatives that may be used as component B include magnesium stearate, calcium

stearate, zinc stearate, magnesium 12-hydroxystearate, calcium 12-hydroxystearate, zinc 12-hydroxystearate, magnesium arachidate, calcium arachidate, zinc arachidate, magnesium behenate, calcium behenate, zinc behenate, magnesium lignocerate, calcium lignocerate and zinc lignocerate. Of these, magnesium stearate, calcium stearate, zinc stearate, magnesium arachidate, calcium arachidate, zinc arachidate, magnesium behenate, calcium behenate, zinc behenate, magnesium lignocerate, calcium lignocerate and zinc lignocerate are preferred.

[0074] The content of component B per 100 parts by weight of the base resin is at least 30 parts by weight, preferably at least 45 parts by weight, more preferably at least 60 parts by weight, and even more preferably at least 80 parts by weight. The upper limit in the content is not more than 170 parts by weight, preferably not more than 150 parts by weight, even more preferably not more than 130 parts by weight, and most preferably not more than 110 parts by weight.

[0075] Use may also be made of known metallic soap-modified ionomer resins (see, for example, U.S. Pat. Nos. 5,312,857 and 5,306,760, and International Disclosure WO 98/46671) when using above component A.

[0076] The basic inorganic metal compound serving as component C is included for the purpose of neutralizing the acid groups in above components A and B. As mentioned in prior-art examples, when components A and B alone, and in particular metal-modified ionomer resins alone (e.g., metal soap-modified ionomer resins of the types mentioned in the foregoing patent publications, alone), are heated and mixed, as shown below, the metal soap and unneutralized acid groups present on the ionomer resin undergo exchange reactions, generating a fatty acid. Because the fatty acid generated has a low thermal stability and readily vaporizes during molding, it causes molding defects. Moreover, if the fatty acid thus generated deposits on the surface of the molding, it will substantially lower paint film adhesion.



[0077] (1) unneutralized acid group present on the ionomer resin

[0078] (2) metallic soap

[0079] (3) fatty acid

[0080] X: metal atom

[0081] A basic inorganic metal compound which neutralizes the acid groups present in above components A and B is thus included as component C in order to resolve such problems. The inclusion of component C as an essential ingredient confers excellent properties. That is, the acid groups in above components A and B are neutralized, and synergistic effects from the inclusion of each of these components increase the thermal stability of the resin composition while at the same time conferring a good moldability and enhancing the resilience as a golf ball material.

[0082] It is recommended that component C be a basic inorganic metal compound—preferably a monoxide or hydroxide—which is capable of neutralizing acid groups in above components A and B. Because such compounds have a

high reactivity with the ionomer resin and the reaction by-products contain no organic matter, the degree of neutralization of the resin composition can be increased without a loss of thermal stability.

[0083] The metal ions used here in the basic inorganic metal compound are exemplified by Li^+ , Na^+ , K^+ , Ca^{2+} , Mg^{2+} , Zn^{2+} , Al^{3+} , Ni^{2+} , Fe^{2+} , Fe^{3+} , Cu^{2+} , Mn^{2+} , Sn^{2+} , Pb^{2+} and Co^{2+} . Illustrative examples of the inorganic metal compound include basic inorganic fillers containing these metal ions, such as magnesium oxide, magnesium hydroxide, magnesium carbonate, zinc oxide, sodium hydroxide, sodium carbonate, calcium oxide, calcium hydroxide, lithium hydroxide and lithium carbonate. Of these, as noted above, a monoxide or hydroxide is preferred. The use of magnesium oxide or calcium hydroxide, which have high reactivities with ionomer resins, is especially preferred.

[0084] The content of component C may be suitably selected so as to obtain the desired degree of neutralization. Although not subject to any particular limitation, component C may be set to a content of, based on the acid groups in component A and B, preferably at least 30 mol %, more preferably at least 45 mol %, even more preferably at least 60 mol %, and most preferably at least 70 mol %. The upper limit may be set to preferably not more than 130 mol %, more preferably not more than 110 mol %, even more preferably not more than 100 mol %, and most preferably not more than 90 mol %. The above content, expressed on a weight basis per 100 parts by weight of the base resin, is preferably from 0.1 to 10 parts by weight. In this case, the lower limit is more preferably at least 0.5 part by weight, even more preferably at least 0.8 part by weight, and most preferably at least 1 part by weight. On the other hand, the upper limit is more preferably not more than 8 parts by weight, even more preferably not more than 5 parts by weight, and most preferably not more than 4 parts by weight.

[0085] The above resin composition has a melt flow rate, measured in accordance with JIS-K6760 (test temperature, 190° C.; test load, 21 N (2.16 kgf)), of preferably at least 1 g/10 min, more preferably at least 2 g/10 min, and even more preferably at least 3 g/10 min. The upper limit is preferably not more than 30 g/10 min, more preferably not more than 20 g/10 min, even more preferably not more than 15 g/10 min, and most preferably not more than 10 g/10 min. If the melt flow rate of this resin composition is low, the processability may markedly decrease.

[0086] The method of preparing the above resin composition is not subject to any particular limitation, although use may be made of a method which involves charging the ionomer resins or unneutralized polymers of components A-I and A-II, together with components B and C, into a hopper and extruding under the desired conditions. Alternatively, component B may be charged from a separate feeder. The neutralization reaction by above component C as the metal cation source with the carboxylic acids in components A-I, A-II and B may be carried out with various types of extruders. Here, either a single-screw extruder or a twin-screw extruder may be used as the extruder, although the use of a twin-screw extruder is more preferred because of the large kneading effect. Alternatively, these extruders may be used in a tandem arrangement, such as single-screw extruder/twin-screw extruder or twin-screw extruder/twin-screw extruder. These extruders need not be of a special design; the use of existing extruders will suffice.

[0087] The method of forming the above first layer using a thermoplastic resin is not subject to any particular limitation. Use may be made of a known method such as forming or injection molding, with production by injection molding being especially preferred. In such a case, preferred use may be made of a method in which the above-described thermoplastic resin material is injected into the cavity of a core-forming mold.

[0088] The diameter of the first layer is set to from 3 to 24 mm. Here, the lower limit in the diameter is preferably at least 5 mm, more preferably at least 7 mm, and even more preferably at least 9 mm. The upper limit in the diameter is preferably not more than 20 mm, and more preferably not more than 15 mm. If the diameter falls outside the above range, a sufficient initial velocity may not be obtained when the ball is struck with a W#1, as a result of which a good distance may not be achieved.

[0089] The second layer is a layer which encases the above-described first layer and, of the three layers making up the solid core, is the layer positioned in the middle. This second layer is not subject to any particular limitation, although it may be formed using a material similar to the material used to form the first layer. That is, advantageous use can be made of a rubber composition in which the above-described polybutadiene serves as the base rubber, or of a thermoplastic resin.

[0090] The method of forming the second layer using a rubber composition may be a known method and is not subject to any particular limitation, although preferred use may be made of the following method. First, the second layer-forming material is placed in a predetermined mold and subjected to primary vulcanization (semi-vulcanization) so as to produce a pair of hemispherical half-cups. The prefabricated spherical first layer is then enclosed within the half-cups produced as just described, in which state secondary vulcanization (complete vulcanization) is carried out. That is, advantageous use may be made of a method in which the vulcanization step is divided into two stages. Alternatively, advantageous use may be made of a method in which the second layer-forming material is injection-molded over the first layer.

[0091] In cases where the first layer has been formed of a thermoplastic resin, a firm bond may be achieved at the interface between the first layer and the second layer by pre-coating the surface of the first layer with an adhesive. By firmly bonding both layers with an adhesive, the durability of the golf ball is further enhanced, enabling a high rebound to be achieved. Alternatively, adherence between the first layer and the second layer can be further increased by subjecting the surface of the first layer to pretreatment, such as grinding treatment with a barrel finishing machine, plasma treatment, corona discharge treatment or chemical treatment, so as to form fine surface irregularities on the surface.

[0092] The method of forming the second layer using a thermoplastic resin is also not subject to any particular limitation. A known method may be employed, such as the method of injection-molding a second layer-forming material over the sphere serving as the first layer, or the method of prefabricating a pair of hemispherical half-cups from the second layer-forming material, enclosing the first layer within these half-cups, and molding under applied heat and pressure at from 140 to 180° C. for a period of 2 to 10 minutes.

[0093] The sphere composed of the first layer encased by the second layer (second layer-covered sphere) has a diameter which, although not subject to any particular limitation, may be set to from 20 to 33 mm. In this case, the lower limit in the diameter is preferably at least 23 mm, and more preferably at least 25 mm. The upper limit is preferably not more than 30 mm, and more preferably not more than 28 mm.

[0094] The third layer is a layer which encases the second layer. Of the three layers making up the solid core, the third layer is the layer positioned on the outermost side. It is critical that this third layer be formed of a rubber composition composed primarily of polybutadiene. In particular, use can be made of a rubber composition similar to the rubber composition which may be advantageously used to form the first layer.

[0095] The method of forming the third layer is not subject to any particular limitation, although preferred use may be made of a method similar to the method of forming the second layer. That is, advantageous use may be made of a method in which a third layer-forming material is placed in a predetermined mold and subjected to primary vulcanization (semi-vulcanization) to fabricate a pair of hemispherical half-cups, following which a prefabricated second layer-covered sphere is enclosed within the fabricated half-cups and secondary vulcanization (complete vulcanization) is carried out in this state; or a method in which the third layer-forming material is injection-molded over the second layer.

[0096] When the second layer has been formed of a thermoplastic resin, a firm bond may be achieved at the interface between the second layer and the third layer by pre-coating the surface of the second layer with an adhesive. By firmly bonding both layers with an adhesive, the durability of the golf ball is further enhanced, enabling a higher rebound to be achieved. Alternatively, adherence between the second layer and the third layer can be further increased by subjecting the surface of the second layer to grinding treatment with a barrel finishing machine, plasma treatment, corona discharge treatment, chemical treatment or the like so as to form fine surface irregularities on the surface.

[0097] The solid core obtained by successively forming the above first to third layers as described above has a diameter which, although not subject to any particular limitation, is preferably from 33 to 41 mm. The lower limit in this diameter is more preferably at least 35 mm, and even more preferably at least 37 mm. The upper limit is more preferably not more than 40 mm, and even more preferably not more than 39 mm.

[0098] In the present invention, a solid core having a first, second and third layer has been optimized by setting the cross-sectional hardness of the core so as to gradually decrease from the first layer toward the third layer. More specifically, letting (a) represent the cross-sectional hardness, expressed as the JIS-C hardness, at a center of the core on a cut face when the solid core has been cut in half, (b) represent the cross-sectional hardness, expressed as the JIS-C hardness, of the first layer 1 mm inside an interface between the first layer and the second layer, (c) represent the cross-sectional hardness, expressed as the JIS-C hardness, of the second layer 1 mm outside the interface between the first layer and the second layer, (d) represent the cross-sectional hardness, expressed as the JIS-C hardness, of the second layer 1 mm inside an interface between the second layer and the third layer, (e) represent the cross-sectional hardness, expressed as the JIS-C hardness, of the third layer 1 mm outside the interface between the second layer and the third layer, and (f) represent the surface hardness, expressed as the JIS-C hardness, of the third layer, it is critical for:

[0099] the value (b)–(c) to be in a range of from 0 to 40;

[0100] the value (e)–(d) to be in a range of from –40 to 0; and

[0101] the value (a)+(b)+(c)+(d)+(e)+(f) to be in a range of from 430 to 490.

[0102] The sectional hardnesses (a) to (f) at various cross-sectional areas of the solid core are described in detail below.

[0103] The cross-sectional hardness (a) at the center of the core, although not subject to any particular limitation, may be set to a value, expressed as the JIS-C hardness, of at least 70, preferably at least 75, and more preferably at least 80. The upper limit, although not subject to any particular limitation, may be set to a value, expressed as the JIS-C hardness, of not more than 95, preferably not more than 90, and more preferably not more than 85. If the cross-sectional hardness (a) is too small, a sufficient initial velocity may not be obtained on shots with a W#1. On the other hand, if it is too large, the spin rate on shots with a W#1 may be excessive.

[0104] The cross-sectional hardness (b) of the first layer 1 mm inside an interface between the first layer and the second layer, although not subject to any particular limitation, may be set to a value, expressed as the JIS-C hardness, of at least 70, preferably at least 75, and more preferably at least 80. The upper limit, although not subject to any particular limitation, may be set to a value, expressed as the JIS-C hardness, of not more than 95, and preferably not more than 90.

[0105] The cross-sectional hardness (c) of the second layer 1 mm outside the interface between the first layer and the second layer, although not subject to any particular limitation, may be set to a value, expressed as the JIS-C hardness, of at least 50, preferably at least 55, and more preferably at least 60. The upper limit, although not subject to any particular limitation, may be set to a value, expressed as the JIS-C hardness, of not more than 80, preferably not more than 75, and even more preferably not more than 70.

[0106] The cross-sectional hardness (d) of the first layer 1 mm inside an interface between the second layer and the third layer, although not subject to any particular limitation, may be set to a value, expressed as the JIS-C hardness, of at least 60, preferably at least 65, and more preferably at least 70. The upper limit, although not subject to any particular limitation, may be set to a value, expressed as the JIS-C hardness, of not more than 90, preferably not more than 85, and even more preferably not more than 80.

[0107] The cross-sectional hardness (e) of the third layer 1 mm outside the interface between the second layer and the third layer, although not subject to any particular limitation, may be set to a value, expressed as the JIS-C hardness, of at least 60, preferably at least 65, and more preferably at least 70. The upper limit, although not subject to any particular limitation, may be set to a value, expressed as the JIS-C hardness, of not more than 90, preferably not more than 85, and even more preferably not more than 80.

[0108] The surface hardness (f) of the third layer, although not subject to any particular limitation, may be set to a value, expressed as the JIS-C hardness, of at least 60, preferably at least 65, and more preferably at least 70. The upper limit, although not subject to any particular limitation, may be set to a value, expressed as the JIS-C hardness, of not more than 95, preferably not more than 90, and more preferably not more than 85.

[0109] The value (b)–(c), as mentioned above, must be set to from 0 to 40. The lower limit in this value is preferably at least 5, and more preferably at least 10. The upper limit in this value is preferably not more than 30, and more preferably not more than 20. If the value (b)–(c) is too large, the durability to cracking may be inadequate; if it is too small, a sufficient initial velocity may not be obtained on shots with a W#1.

[0110] The value (e)–(d), as mentioned above, must be set to from –40 to 0. The lower limit in this value is preferably at least –20, and more preferably at least –10. The upper limit in this value is preferably not more than –5. If the value (e)–(d) is too large, the feel of the ball on impact may become too hard; if it is too small, a sufficient initial velocity may not be obtained on shots with a W#1.

[0111] The value (f)–(a), although not subject to any particular limitation, is preferably set to from –10 to 10. The lower limit in this value is more preferably at least –7, and even more preferably at least –5. The upper limit in this value is preferably not more than 7, and more preferably not more than 5. If the value (f)–(a) is too large, the durability to cracking may be inadequate; if it is too small, the feel on impact may become too hard.

[0112] The value (a)+(b)+(c)+(d)+(e)+(f), as mentioned above, must be set to from 430 to 490. The lower limit in this value is more preferably at least 440, and even more preferably at least 450. The upper limit in this value is more preferably not more than 480, and even more preferably not more than 470. If the value (a)+(b)+(c)+(d)+(e)+(f) is too large, the feel on impact may become too hard; if it is too small, a sufficient initial velocity may not be obtained on shots with a W#1.

[0113] As noted above, by optimizing the cross-sectional hardnesses (a) to (f) of various cross-sectional areas of the solid core, the rebound of the ball when hit becomes very high and a good feel on impact can be obtained.

[0114] The diameter ratio between the first layer and the second layer-covered sphere (first layer diameter/second layer-covered sphere diameter), although not subject to any particular limitation, is preferably from 0.20 to 0.50. The lower limit in this diameter ratio is more preferably at least 0.25, and even more preferably at least 0.30. If the diameter ratio is too large, the spin rate on shots with a W#1 may become too high. On the other hand, if the diameter ratio is too small, a sufficient initial velocity on shots with a W#1 may not be obtained.

[0115] The ratio between the volume of the second layer (the volume of the second layer alone; that is, not including the first layer) and the volume of the solid core (second layer volume/solid core volume), although not subject to any particular limitation, is preferably set to from 0.10 to 0.50. Here, the lower limit in the volume ratio is more preferably at least 0.15, even more preferably at least 0.20, and most preferably at least 0.25. The upper limit in the volume ratio is more preferably not more than 0.40, and even more preferably not more than 0.30. If the volume ratio is too large, the spin rate on shots with a W#1 may become too high. On the other hand, if the volume ratio is too small, a sufficient initial velocity may not be obtained on shots with a W#1.

[0116] In the multi-piece solid golf ball of the invention, a cover of one, two or more layers is formed so as to encase the solid core. In this invention, although not subject to any particular limitation, a known cover material may be used as the material which forms this cover. Illustrative examples include known thermoplastic resins, ionomer resins, highly neutralized ionomer resin compositions such as those described above, thermoplastic and thermoset polyurethanes, and polyamide-type and polyester-type thermoplastic elastomers. Conventional injection molding may be advantageously used to form the cover.

[0117] In the invention, of the above-described cover materials, the use of, for example, ionomer resins, highly neutral-

ized ionomer resin compositions, thermoplastic polyurethanes and polyester-type thermoplastic elastomers is preferred. It is especially recommended that an ionomer resin be used. In cases where the cover is composed of a single layer, although not subject to any particular limitation, it is preferable to set the thickness to from 0.5 to 2.0 mm, and it is preferable to set the cover material hardness, expressed as the Shore D hardness, to from 30 to 65. As used herein, “cover material hardness” refers to the hardness of the cover material when molded into a sheet of a predetermined thickness.

[0118] When the cover is composed of two or more layers, the thickness of the inner cover layer, although not subject to any particular limitation, may be set to preferably at least 0.5 mm, more preferably at least 0.7 mm, even more preferably at least 0.9 mm, and most preferably at least 1.1 mm. The upper limit also is not subject to any particular limitation, but may be set to preferably not more than 3 mm, more preferably not more than 2.5 mm, even more preferably not more than 2 mm, and most preferably not more than 1.5 mm. The material hardness of the inner cover layer, expressed as the Shore D hardness, although not subject to any particular limitation, may be set to preferably at least 30, more preferably at least 35, even more preferably at least 40, and most preferably at least 45. The upper limit, although not subject to any particular limitation, may be set to preferably not more than 58, more preferably not more than 56, even more preferably not more than 54, and most preferably not more than 52.

[0119] The thickness of the outer cover layer, although not subject to any particular limitation, may be set to preferably at least 0.5 mm, more preferably at least 0.7 mm, even more preferably at least 0.9 mm, and most preferably at least 1.1 mm. The upper limit also is not subject to any particular limitation, but may be set to preferably not more than 3 mm, more preferably not more than 2.5 mm, even more preferably not more than 2 mm, and most preferably not more than 1.5 mm. The material hardness of the outer cover layer, expressed as the Shore D hardness, although not subject to any particular limitation, may be set to preferably at least 55, more preferably at least 56, and even more preferably at least 57. The upper limit, although not subject to any particular limitation, may be set to preferably not more than 70, more preferably not more than 65, and even more preferably not more than 63.

[0120] By forming the cover as described above, in addition to a distance-increasing effect, a good feel and a good scuff resistance can both be achieved.

[0121] The diameter of the golf ball in which the above-described core and cover are formed should accord with golf ball standards, and is preferably not less than 42.67 mm. The upper limit, although not subject to any particular limitation, may be set to preferably not more than 44 mm, more preferably not more than 43.8 mm, even more preferably not more than 43.5 mm, and most preferably not more than 43 mm.

[0122] In the above range in the golf ball diameter, the deflection of the ball as a whole when compressed under a final load of 1,275 N (130 kgf) from an initial load of 98 N (10 kgf) (which deflection is also called the “product hardness”), although not subject to any particular limitation, is preferably at least 2.0 mm, more preferably at least 2.2 mm, and even more preferably at least 2.4 mm. The upper limit, although not subject to any particular limitation, is preferably not more than 5.0 mm, more preferably not more than 4.5 mm, even more preferably not more than 4.0 mm, and most preferably not more than 3.5 mm. If the above deflection is too large, a sufficient

initial velocity may not be obtained on shots with a W#1. On the other hand, if the deflection is too small, the spin rate on shots with a W#1 may become too high.

[0123] In addition, the deflection of the ball as a whole when compressed under a final load of 5,880 N (600 kgf) from an initial load of 98 N (10 kgf), although not subject to any particular limitation, is preferably at least 7.2 mm, more preferably at least 7.6 mm, and even more preferably at least 8 mm. The upper limit, although not subject to any particular limitation, is preferably not more than 14 mm, more preferably not more than 12 mm, and even more preferably than 10 mm. If the above deflection is too large, a sufficient initial velocity may not be obtained on shots with a W#1. On the other hand, if the deflection is too small, the spin rate on shots with a W#1 may become too high.

[0124] In addition, although not subject to any particular limitation, the ratio between the deflection of the second layer-covered sphere when compressed under a final load of 1,275 N (130 kgf) from an initial load of 98 N (10 kgf) to the deflection of the solid core when compressed under a final load of 1,275 N (130 kgf) from an initial load of 98 N (10 kgf) (second layer-covered sphere deflection/solid core deflection) is preferably from 0.90 to 1.20. The lower limit in the above deflection ratio is more preferably at least 0.95, and even more preferably at least 1.00. The upper limit in this deflection ratio is more preferably not more than 1.15, and even more preferably not more than 1.10. If this deflection ratio is too large, the spin rate on shots with a W#1 may become too high. On the other hand, if this deflection ratio is too low, it may not be possible to obtain a sufficient initial velocity on shots with a W#1.

[0125] Although not subject to any particular limitation, the ratio between the deflection of the solid core when compressed under a final load of 1,275 N (130 kgf) from an initial load of 98 N (10 kgf) to the deflection of the ball as a whole when compressed under a final load of 1,275 N (130 kgf) from an initial load of 98 N (10 kgf) (solid core deflection/ball deflection) is preferably from 1.00 to 1.30. The lower limit in this deflection ratio is more preferably at least 1.05. The upper limit in this deflection ratio is more preferably not more than 1.20, and even more preferably not more than 1.15. If this deflection ratio is too large, the feel of the ball on impact may become too hard, whereas if the deflection ratio is too small, the spin rate of the ball on shots with a W#1 may become too high.

[0126] Moreover, although not subject to any particular limitation, the ratio between the deflection of the ball as a whole when compressed under a final load of 5,880 N (600 kgf) from an initial load of 98 N (10 kgf) to the deflection of the ball as a whole when compressed under a final load of 1,275 N (130 kgf) from an initial load of 98 N (10 kgf) (600 kgf deflection/130 kgf deflection) is preferably from 3.30 to 3.70. The upper limit in this deflection ratio is more preferably not more than 3.60, and even more preferably not more than 3.50. If this deflection ratio is too large, a sufficient initial velocity may not be achieved on shots with a W#1. On the other hand, if the deflection ratio is too small, the spin rate of the ball on shots with a W#1 may become too high.

[0127] In the golf ball of the invention, in order to further increase the aerodynamic properties and extend the distance traveled by the ball, as in conventional golf balls, numerous dimples may be formed on the surface of the cover. In this case, the number of dimples formed on the ball surface, although not subject to any particular limitation, is preferably

at least 280, more preferably at least 300, and even more preferably at least 320. The upper limit in the number of dimples, although not subject to any particular limitation, may be set to preferably not more than 400, more preferably not more than 380, and even more preferably not more than 350. If the number of dimples is higher than the above range, the trajectory of the ball may become low, as a result of which a good distance may not be achieved. On the other hand, if the number of dimples is lower than the above range, the trajectory may become high, as a result of which an increased distance may not be achieved.

[0128] The geometric arrangement of the dimples on the ball may be, for example, octahedral or icosahedral. In addition, the dimple shapes may be of one, two or more types suitably selected from among not only circular shapes, but also various polygonal shapes, such as square, hexagonal, pentagonal and triangular shapes, as well as dewdrop shapes and oval shapes. The diameter (in a polygonal shape, the length of the diagonal), although not subject to any particular limitation, is preferably set to from 2.5 to 6.5 mm. The depth also, although not subject to any particular limitation, is preferably set to from 0.08 to 0.30 mm.

[0129] The value V_o , defined as the spatial volume of a dimple below the flat plane circumscribed by the dimple edge, divided by the volume of the cylinder whose base is the flat plane and whose height is the maximum depth of the dimple from the base, although not subject to any particular limitation, may be set to from 0.35 to 0.80 in this invention.

[0130] The ratio SR of the sum of individual dimple surface areas, each defined by the flat plane circumscribed by the edge of a dimple, with respect to the surface area of the ball sphere were the ball surface to have no dimples thereon, although not subject to any particular limitation, is preferably set to from 60 to 90% from the standpoint of reducing aerodynamic resistance. This SR can be elevated by increasing the number of dimples formed, and also by intermingling dimples of a plurality of types having different diameters or by having the dimple shapes be such that the distance between neighboring dimples (land width) becomes substantially 0.

[0131] The ratio VR of the sum of the spatial volumes of individual dimples formed below the flat plane circumscribed by the edge of a dimple with respect to the surface area of the ball sphere were the ball surface to have no dimples thereon, although not subject to any particular limitation, is preferably set to from 0.6 to 1 in this invention.

[0132] In the invention, by setting the above V_o , SR and VR values in the foregoing ranges, the aerodynamic resistance is reduced, in addition to which a trajectory enabling a good distance to be achieved readily arises and the flight performance can be enhanced.

[0133] Moreover, the ball surface may be subjected to various types of treatment, such as surface preparation, stamping and painting, in order to enhance the design and durability of the golf ball.

[0134] As explained above, the present invention, by optimizing the hardness relationships among the various layers of the core having a multilayer structure, enables a golf ball to be obtained which has an increased initial velocity, particularly when struck in a high head speed range, and thus can be expected to travel an increased distance. The golf ball of the invention is also capable of having a good feel on impact.

EXAMPLES

[0135] Examples of the invention and Comparative Examples are given below by way of illustration, and not by way of limitation.

Examples 1 to 6, Comparative Examples 1 to 10

[0136] The rubber compositions shown in Table 1 below were prepared, then molded and vulcanized at 155° C. for 15 minutes to produce a spherical molding as the first layer. However, in Example 2, a spherical molding was obtained by injection molding using the resin material shown as No. 1 in Table 3.

[0137] With regard to the second layer, in the respective examples, first a pair of hemispherical half-cups was produced by using mixing rolls to knead the rubber composition shown in Table 2, then carrying out primary vulcanization (semi-vulcanization) at 130° C. for 6 minutes. Next, the first layer was enclosed within the resulting half-cups and the second layer was formed by secondary vulcanization (complete vulcanization) in a mold at 155° C. for 15 minutes, thereby producing a second layer-covered sphere.

[0138] The third layer was formed by the same method as the second layer. More specifically, the rubber composition shown in Table 2 was kneaded using mixing rolls, then subjected to primary vulcanization (semi-vulcanization) at 130° C. for 6 minutes, thereby producing a pair of hemispherical half-cups. Next, the second layer-covered sphere was enclosed within the resulting half-cups and the third layer was formed by secondary vulcanization (complete vulcanization) in a mold at 155° C. for 15 minutes, thereby producing a solid core having a three-layer structure. In Comparative Example 10, the third layer was formed by injecting the resin material shown as No. 2 in Table 3 over the second layer.

[0139] Next, the resin material (cover material) having the composition shown in Table 3 was injection-molded over the respective solid cores, thereby forming in each case both an inner cover layer (intermediate layer) and an outer cover layer having on the surface dimples of the same shape, arrangement and number. This gave multi-piece solid golf balls composed of a solid core having a three-layer structure encased by a two-layer cover. The dimples shown in FIG. 1 were formed at this time on the cover surface. Details on the dimples are shown in Table 4.

TABLE 1

	A	B	C	D	E
Polybutadiene rubber	100	100	100	100	100
Zinc acrylate	41.0	38.0	25.0	32.5	19.5
Peroxide	3	3	3	3	3
Zinc oxide	5	5	5	5	5
Barium sulfate	16.6	17.9	23.3	20.1	25.6
Antioxidant	0.1	0.1	0.1	0.1	0.1
Zinc salt of pentachlorothiophenol	0.4	0.4	0.4	0.4	0.4

*Numbers in the table indicate parts by weight.

TABLE 2

	F	G	H	I	J	K	L	M
Polybutadiene rubber	100	100	100	100	100	100	100	100

TABLE 2-continued

	F	G	H	I	J	K	L	M
Zinc acrylate	29.0	29.0	35.0	22.0	31.0	32.5	28.0	36.0
Peroxide	3	3	3	3	3	3	3	3
Zinc oxide	5	5	5	5	5	5	5	5
Barium sulfate	21.6	14.2	19.1	24.5	20.8	12.9	22	18.9
Antioxidant	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Zinc salt of pentachlorothiophenol	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.1

*Numbers in the table indicate parts by weight.

[0140] Details on the materials in Tables 1 and 2 are given below.

[0141] Polybutadiene rubber: Available as “BR 730” from JSR Corporation. A polybutadiene rubber obtained using a neodymium catalyst; cis-1,4 bond content, 96 wt %; Mooney viscosity, 55; molecular weight distribution, 3.

[0142] Zinc acrylate: Available from Nihon Jyoryu Kogyo Co., Ltd.

[0143] Peroxide: Available as “Perhexa C-40” from NOF Corporation. 1,1-Bis(t-butylperoxy)cyclohexane diluted to 40% with an inorganic filler. Half-life at 155° C., about 50 seconds.

[0144] Zinc oxide: Available from Sakai Chemical Co., Ltd.

[0145] Barium sulfate: Available as “Precipitated Barium Sulfate 100” from Sakai Chemical Co., Ltd.

[0146] Antioxidant: Available as “Nocrac NS-6” from Ouchi Shinko Chemical Industry Co., Ltd.

TABLE 3

	No. 1	No. 2	No. 3	No. 4	No. 5
Surlyn 6320	60				
Nucel N035C	40				
HPF2000		100			
Himilan 1605			50		
Himilan 1706			35		
Himilan 1557			15	50	
Himilan 1601				50	
Pandex T8295					100
Magnesium stearate	69			0.6	
Magnesium oxide	0.8				
Trimethylolpropane			1.1		
Polyisocyanate compound					9
Hytrel 4001					15
Titanium oxide				2.4	3.5
Polyethylene wax					1.5

*Numbers in the table indicate parts by weight.

[0147] Details on the materials in Table 3 are given below.

[0148] Surlyn: An ionomer resin available from E.I. DuPont de Nemours and Co.

[0149] Nucel N035C: An ethylene-methacrylic acid-ester terpolymer available from DuPont-Mitsui Polychemicals Co., Ltd.

[0150] Himilan: Ionomer resins available from DuPont-Mitsui Polychemicals Co., Ltd.

[0151] Dynaron 6100P: A hydrogenated polymer available from JSR Corporation.

[0152] Pandex: A MDI-PTMG type thermoplastic polyurethane available from DIC Bayer Polymer

[0153] Magnesium stearate: Available as “Magnesium Stearate G” from NOF Corporation.

- [0154] Magnesium oxide: Available as “Kyowamag MF150” from Kyowa Chemical Industry Co., Ltd.
- [0155] Behenic acid: Available as “NAA-222S” from NOF Corporation
- [0156] Calcium hydroxide: Available as “CLS-B” from Shiraishi Calcium Kaisha, Ltd.
- [0157] Polyisocyanate compound: 4,4'-Diphenylmethane diisocyanate
- [0158] Hytrel: A thermoplastic polyester elastomer available from DuPont-Toray Co., Ltd.
- [0159] Titanium oxide: Available as “Tipaue R550” from Ishihara Sangyo Kaisha, Ltd.
- [0160] Polyethylene wax: Available as “Sanwax 161P” from Sanyo Chemical Industries, Ltd.

TABLE 4

No.	Number of dimples	Diameter (mm)	Depth (mm)	V ₀	SR	VR
1	18	4.6	0.13	0.53	81.6	0.819
2	234	4.5	0.14	0.53		
3	42	3.7	0.14	0.53		
4	12	3.3	0.13	0.53		
5	6	3.0	0.16	0.53		
6	14	3.5	0.14	0.53		
Total	326					

Dimple Definitions

- [0161] Diameter: Diameter of flat plane circumscribed by edge of dimple.
- [0162] Depth: Maximum depth of dimple from flat plane circumscribed by edge of dimple.
- [0163] V₀: Spatial volume of dimple below flat plane circumscribed by dimple edge, divided by volume of cylinder whose base is the flat plane and whose height is the maximum depth of dimple from the base.
- [0164] SR: Sum of individual dimple surface areas, each defined by the flat plane circumscribed by the edge of a dimple, as a percentage of surface area of hypothetical sphere were the ball to have no dimples on the surface thereof (units: %).
- [0165] VR: Sum of spatial volumes of individual dimples formed below flat plane circumscribed by the edge of the dimple, as a percentage of volume of hypothetical sphere were the ball to have no dimples on the surface thereof (units: %).
- [0166] The following properties were investigated for the golf balls obtained. Also, flight tests were carried out by the following methods, in addition to which the feel on impact was evaluated. The results are shown in Tables 5 to 8.

Cross-Sectional Hardnesses and Surface Hardness of Solid Core (JIS-C Hardness)

- [0167] To determine the center and cross-sectional hardnesses of the solid core, the core was cut into two through the center thereof and the cut face was rendered planar, following which a durometer indenter was pressed perpendicularly against the cut face at predetermined positions and measurement carried out. The hardnesses are indicated as JIS-C hardness values.
- [0168] To determine the surface hardness of the solid core, the durometer was set perpendicular to the surface portion of

the spherical core and the hardness was measured based on the JIS-C hardness standard. The hardnesses are indicated as JIS-C hardness values. The measured values were obtained after holding the solid cores isothermally at 23° C.

[0169] The specific places where measurement of the cross-sectional hardness and the surface hardness was carried out were as follows.

- [0170] (a) center of core
- [0171] (b) first layer 1 mm inside interface between first layer and second layer
- [0172] (c) second layer 1 mm outside interface between first layer and second layer
- [0173] (d) second layer 1 mm inside interface between second layer and third layer
- [0174] (e) third layer 1 mm outside interface between second layer and third layer
- [0175] (f) surface of third layer

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

[0176] The material hardness of the cover was a value measured with a type D durometer according to ASTM D2240 for measurement samples of the cover material prepared in the form of 6 mm thick sheets.

Deflection

[0177] Using a model 4204 test system manufacturing by Instron Corporation, the balls, the second layer-covered spheres and the solid cores were each compressed at a rate of 10 mm/min, and the deflection when compressed under a final load of 1,275 N (130 kgf) from an initial load of 98 N (10 kgf) was measured. In addition, the deflection when compressed under a final load of 5,880 N (600 kgf) from an initial load of 98 N (10 kgf) was similarly measured.

Initial Velocity of Ball

[0178] The initial velocity was measured using an initial velocity measuring apparatus of the same type as the USGA drum rotation-type initial velocity instrument approved by the R&A. The balls were held isothermally at a temperature of 23±1° C. for at least 3 hours, then tested in a room temperature (23±2° C.) chamber. Ten balls were each hit twice, and the time taken for the balls to traverse a distance of 6.28 ft (1.91 m) was measured and used to compute the initial velocity.

Distance with W#1

[0179] Each ball was hit ten times at a head speed (HS) of 50 m/s with a Tour Stage X-Drive (loft angle, 10.5°) driver (W#1), manufactured by Bridgestone Sports Co., Ltd., mounted on a golf swing robot, and the spin rate (rpm) and total distance (m) were measured. The initial velocity was measured using a high-speed camera. The distance was rated according to the following criteria.

- [0180] Good: 257 m or more
- [0181] NG: less than 257 m

Feel

- [0182] The feel of the ball when hit with a driver (W#1) at a head speed (HS) of 40 to 50 m/s was rated by three top amateur golfers according to the following criteria.
- [0183] Good: good feel
- [0184] NG: too hard or too soft

TABLE 5

		Example					
		1	2	3	4	5	6
First layer	Material	A	No. 1	B	A	A	A
	Specific gravity	1.20	0.95	1.20	1.20	1.20	1.20
	Diameter (mm)	12.0	12.0	12.0	20.0	12.0	12.0
	Volume (cm ³)	0.9	0.9	0.9	4.2	0.9	0.9
	Weight (g)	1.1	0.9	1.1	5.0	1.1	1.1
	Cross-sectional hardness (JIS-C) (a)	81	82	75	81	81	81
	Cross-sectional hardness (JIS-C) (b)	86	82	79	86	86	86
Second layer	Material	F	F	F	F	F	G
	Specific gravity	1.20	1.20	1.20	1.20	1.20	1.16
	Diameter (mm)	26.0	26.0	26.0	26.0	30.0	26.0
	Volume (cm ³)	8.3	8.3	8.3	5.0	13.2	8.3
	Weight (g)	10.0	10.0	10.0	6.0	15.9	9.6
	Thickness (mm)	7.0	7.0	7.0	3.0	9.0	7.0
	Deflection (mm)	2.8	2.9	3.1	2.6	2.7	2.8
	Cross-sectional hardness (JIS-C) (c)	69	69	69	69	69	69
Third layer	Cross-sectional hardness (JIS-C) (d)	78	78	78	78	78	78
	Material	J	J	J	J	J	K
	Specific gravity	1.20	1.20	1.20	1.20	1.20	1.16
	Diameter (mm)	37.7	37.7	37.7	37.7	37.7	38.5
	Volume (cm ³)	18.8	18.8	18.8	18.8	13.9	20.7
	Weight (g)	22.6	22.6	22.6	22.6	16.7	24.0
	Thickness (mm)	5.9	5.9	5.9	5.9	3.9	6.3
	Deflection (mm)	2.8	2.8	2.9	2.65	2.65	2.8
Hardness relationship	Cross-sectional hardness (JIS-C) (e)	71	71	71	71	71	72
	Surface hardness (f) (JIS-C)	80	80	80	80	80	82
	(b) - (c) (JIS-C)	17	13	10	17	17	17
	(e) - (d) (JIS-C)	-7	-7	-7	-7	-7	-6
	(a) + (b) + (c) + (d) + (e) + (f) (JIS-C)	465	462	452	465	465	468
	(f) - (a) (JIS-C)	-1	-2	5	-1	-1	1
	Diameter ratio	0.46	0.46	0.46	0.77	0.40	0.46
	Volume ratio	0.30	0.30	0.30	0.18	0.47	0.28

TABLE 6

		Comparative Example									
		1	2	3	4	5	6	7	8	9	10
First layer	Material	C	D	D	A	A	B	A	E	E	A
	Specific gravity	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.32
	Diameter (mm)	28.0	28.0	37.7	25.0	12.0	12.0	12.0	12.0	12.0	12.0
	Volume (cm ³)	11.5	11.5	28.0	8.2	0.9	0.9	0.9	0.9	0.9	0.9
	Weight (g)	13.8	13.8	33.6	9.8	1.1	1.1	1.1	1.1	1.1	1.2
	Cross-sectional hardness (JIS-C) (a)	59	65	65	81	81	75	81	56	56	81
	Cross-sectional hardness (JIS-C) (b)	67	77	82	86	86	79	86	61	61	86
Second layer	Material				F	H	I	I	I	F	F
	Specific gravity				1.20	1.20	1.20	1.20	1.20	1.20	1.32
	Diameter (mm)				30.0	26.0	26.0	26.0	26.0	26.0	33.0
	Volume (cm ³)				6.0	8.3	8.3	8.3	8.3	8.3	17.9
	Weight (g)				7.1	10.0	10.0	10.0	10.0	10.0	23.6
	Thickness (mm)				2.5	7.0	7.0	7.0	7.0	7.0	10.5
	Deflection (mm)				2.5	2.5	4.0	3.9	4.8	3.6	2.8
	Cross-sectional hardness (JIS-C) (c)				69	77	62	62	62	69	69
	Cross-sectional hardness (JIS-C) (d)				75	85	68	68	68	78	78

TABLE 6-continued

		Comparative Example									
		1	2	3	4	5	6	7	8	9	10
Third layer	Material	J	J		L	M	L	J	J	J	No. 2
	Specific gravity	1.20	1.20		1.20	1.20	1.20	1.20	1.20	1.20	0.95
	Diameter (mm)	37.7	37.7		37.7	37.7	37.7	37.7	37.7	37.7	37.7
	Volume (cm ³)	16.6	16.6		13.9	18.8	18.8	18.8	18.8	18.8	9.2
	Weight (g)	19.9	19.9		16.7	22.6	22.6	22.6	22.6	22.6	8.8
	Thickness (mm)	18.9	18.9		3.9	5.9	5.9	5.9	5.9	5.9	2.4
	Deflection (mm)	3.8	3.0	3.4	3.2	2.3	3.6	2.7	3.5	3.7	2.8
	Cross-sectional hardness (JIS-C) (e)	71	71		67	77	67	71	71	71	77
	Surface hardness (f) (JIS-C)	80	80		77	88	77	80	80	80	77
	(b) - (c) (JIS-C)				17	9	17	24	-1	-8	17
Hardness relationship	(e) - (d) (JIS-C)				-8	-8	-1	3	3	-7	-1
	(a) + (b) + (c) + (d) + (e) + (f) (JIS-C)				455	494	428	448	398	415	468
	(f) - (a) (JIS-C)	21	15	17	-4	7	2	-1	24	24	-4
	Diameter ratio				0.83	0.46	0.46	0.46	0.46	0.46	0.36
Volume ratio	Second layer/solid core				0.21	0.30	0.30	0.30	0.30	0.30	0.64

TABLE 7

		Example					
		1	2	3	4	5	6
Inter-mediate layer	Material	No. 1	No. 1	No. 1	No. 1	No. 1	No. 3
	Material hardness (Shore D)	51	51	51	51	51	62
	Specific gravity	0.95	0.95	0.95	0.95	0.95	0.95
	Diameter (mm)	40.2	40.2	40.2	40.2	40.2	41.1
	Volume (mm ³)	6.0	6.0	6.0	6.0	6.0	6.5
	Weight (g)	5.7	5.7	5.7	5.7	5.7	6.1
	Thickness (mm)	1.3	1.3	1.3	1.3	1.3	1.3
Cover	Material	No. 4	No. 4	No. 4	No. 4	No. 4	No. 5
	Material hardness (Shore D)	60	60	60	60	60	56
	Specific gravity	0.97	0.97	0.97	0.97	0.97	1.15
	Volume (mm ³)	6.2	6.2	6.2	6.2	6.2	3.9
	Weight (g)	6.0	6.0	6.0	6.0	6.0	4.4
	Thickness (mm)	1.3	1.3	1.3	1.3	1.3	0.8
	Number of dimples	326	326	326	326	326	326
Ball	Diameter (mm)	42.7	42.7	42.7	42.7	42.7	42.7
	Weight (g)	45.4	45.2	45.4	45.4	45.4	45.4
	Deflection (10-130 kgf) (mm)	2.60	2.60	2.63	2.50	2.50	2.45
	Deflection (10-600 kgf) (mm)	8.90	8.87	8.96	8.34	8.38	8.90
	Initial velocity (m/s)	77.2	77.2	77.2	77.3	77.3	77.2
	Solid core/ball (10-130 kgf)	1.08	1.08	1.10	1.06	1.06	1.14
	Second layer-covered sphere/solid core (10-130 kgf)	1.00	1.04	1.07	0.98	1.02	1.00
Deflection ratios	Ball (600 kgf/130 kgf)	3.42	3.41	3.41	3.34	3.35	3.63
	Initial velocity (m/s)	73.1	73.2	72.9	73.7	73.6	73.5
	Spin rate (rpm)	2830	2880	2775	2978	2948	3057
	Total distance (m)	258.0	258.0	257.8	259.2	259.0	257.8
Feel	Performance rating	good	good	good	good	good	good
		good	good	good	good	good	good

TABLE 8

		Comparative Example									
		1	2	3	4	5	6	7	8	9	10
Inter-mediate layer	Material	No. 1	No. 1	No. 1	No. 1	No. 1	No. 1	No. 1	No. 1	No. 1	No. 1
	Material hardness (Shore D)	51	51	51	51	51	51	51	51	51	51
	Specific gravity	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
	Diameter (mm)	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2
	Volume (mm ³)	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Cover	Weight (g)	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7
	Thickness (mm)	1.3	1.3	20.1	1.3	1.3	1.3	1.3	1.3	1.3	1.3
	Material	No. 4	No. 4	No. 4	No. 4	No. 4	No. 4	No. 4	No. 4	No. 4	No. 4
	Material hardness (Shore D)	60	60	60	60	60	60	60	60	60	60
	Specific gravity	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
Ball	Volume (mm ³)	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2
	Weight (g)	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
	Thickness (mm)	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
	Number of dimples	326	326	326	326	326	326	326	326	326	326
	Diameter (mm)	42.7	42.7	42.7	42.7	42.7	42.7	42.7	42.7	42.7	42.7
Deflection ratios	Weight (g)	45.4	45.4	45.4	45.4	45.4	45.4	45.4	45.4	45.4	45.4
	Deflection (10-130 kgf) (mm)	2.76	2.65	2.60	2.73	2.30	2.90	2.70	2.70	2.66	2.70
	Deflection (10-600 kgf) (mm)	9.80	9.10	9.10	9.00	8.10	10.00	9.47	9.60	9.40	9.30
	Initial velocity (m/s)	77.0	77.2	77.2	77.0	77.2	76.9	77.1	77.1	77.2	77.1
	Solid core/ball (10-130 kgf)	1.38	1.13	1.31	1.17	1.00	1.24	1.00	1.30	1.39	1.04
W#1 HS50	Second layer-covered sphere/solid core (10-130 kgf)				0.78	1.09	1.11	1.44	1.37	0.97	1.00
	Ball (600 kgf/130 kgf)	3.55	3.43	3.50	3.30	3.52	3.45	3.51	3.56	3.53	3.44
	Initial velocity (m/s)	72.1	72.6	72.4	72.7	73.1	72.0	72.1	71.8	72.2	72.5
Feel	Spin rate (rpm)	2631	2791	2680	3007	2834	2706	2662	2562	2749	2892
	Total distance (m)	255.2	256.2	256.0	255.9	258.9	255.2	255.9	255.4	255.6	255.6
	Performance rating	NG	NG	NG	NG	good	NG	NG	NG	NG	NG
		good	good	good	good	NG	good	good	good	good	good

[0185] In Comparative Example 1 in which the core was composed of two layers, the initial velocity on shots with a driver (W#1) was inadequate, as a result of which a good distance was not achieved.

[0186] In Comparative Example 2 in which the core was composed of two layers, the initial velocity on shots with a driver (W#1) was inadequate, as a result of which a good distance was not achieved.

[0187] In Comparative Example 3 in which the core was composed of a single layer, the initial velocity on shots with a driver (W#1) was inadequate, as a result of which a good distance was not achieved.

[0188] In Comparative Example 4 in which the first layer of the core had a large diameter, the spin rate was high, as a result of which a sufficient distance was not achieved.

[0189] In Comparative Example 5, because the value (a)+(b)+(c)+(d)+(e)+(f) was large, the ball at a hard feel on impact.

[0190] In Comparative Example 6, because the value (a)+(b)+(c)+(d)+(e)+(f) was small, the ball had a low initial velocity on shots with a driver (W#1), as a result of which a good distance was not achieved.

[0191] In Comparative Example 7, because the value (e)-(d) was greater than 0, the initial velocity on shots with a driver (W#1) was low, as a result of which a good distance was not achieved.

[0192] In Comparative Example 8, because the value (b)-(c) was less than 0, the initial velocity on shots with a driver (W#1) was low, as a result of which a good distance was not achieved.

[0193] In Comparative Example 9, because the value (b)-(c) and the value (e)-(d) were both greater than 0, a good distance was not achieved.

[0194] In Comparative Example 10, because the third layer of the core was formed using a thermoplastic resin, a good distance was not achieved.

1. A multi-piece solid golf ball comprising a solid core encased by a cover of one, two or more layers, the solid core comprising a spherical first layer, a second layer encasing the first layer and a third layer encasing the second layer, wherein the first layer has a diameter of from 3 to 24 mm; the third layer is formed of a rubber composition composed primarily of polybutadiene rubber; and, letting (a) represent the cross-sectional hardness at a center of the core on a cut face when the solid core has been cut in half, (b) represent the cross-sectional hardness, expressed as the JIS-C hardness, of the first layer 1 mm inside an interface between the first layer and the second layer, (c) represent the cross-sectional hardness, expressed as the JIS-C hardness, of the second layer 1 mm outside the interface between the first layer and the second layer, (d) represent the cross-sectional hardness, expressed as

the JIS-C hardness, of the second layer 1 mm inside an interface between the second layer and the third layer, (e) represent the cross-sectional hardness, expressed as the JIS-C hardness, of the third layer 1 mm outside the interface between the second layer and the third layer, and (f) represent the surface hardness, expressed as the JIS-C hardness, of the third layer:

the value (b)–(c) is in a range of from 0 to 40,
the value (e)–(d) is in a range of from –40 to 0, and
the value (a)+(b)+(c)+(d)+(e)+(f) is in a range of from 430 to 490.

2. The multi-piece solid golf ball of claim 1, wherein the value (f)–(a) in the solid core is in a range of from –10 to 10.

3. The multi-piece solid golf ball of claim 1, wherein the first layer is formed of a rubber composition composed primarily of polybutadiene rubber.

4. The multi-piece solid golf ball of claim 1, wherein the cross-sectional hardness (a) of the solid core, expressed as the JIS-C hardness, is in a range of from 70 to 95.

5. The multi-piece solid golf ball of claim 1, wherein the second layer is formed of a rubber composition composed primarily of polybutadiene rubber.

6. The multi-piece solid golf ball of claim 1, wherein a sphere composed of the first layer encased by the second layer (second layer-covered sphere) has a diameter of from 20 to 33 mm.

7. The multi-piece solid golf ball of claim 1, wherein the diameter ratio between the first layer and the second layer-

covered sphere (first layer diameter/second layer-covered sphere diameter) is from 0.20 to 0.50.

8. The multi-piece solid golf ball of claim 1, wherein the volume ratio between the second layer and the solid core (second layer volume/solid core volume) is from 0.10 to 0.50.

9. The multi-piece solid golf ball of claim 1, wherein the ratio between the deflection of the second layer-covered sphere when compressed under a final load of 1,275 N (130 kgf) from an initial load state of 98 N (10 kgf) to the deflection of the solid core when compressed under a final load of 1,275 N (130 kgf) from an initial load state of 98 N (10 kgf) (second layer-covered sphere deflection/solid core deflection) is from 0.90 to 1.20.

10. The multi-piece solid golf ball of claim 1, wherein the ratio between the deflection of the solid core when compressed under a final load of 1,275 N (130 kgf) from an initial load state of 98 N (10 kgf) to the deflection of the ball when compressed under a final load of 1,275 N (130 kgf) from an initial load state of 98 N (10 kgf) (solid core deflection/ball deflection) is from 1.00 to 1.30.

11. The multi-piece solid golf ball of claim 1, wherein the ratio between the deflection of the ball when compressed under a final load of 5,880 N (600 kgf) from an initial load state of 98 N (10 kgf) and the deflection of the ball when compressed under a final load of 1,275 N (130 kgf) from an initial load state of 98 N (10 kgf) (600 kgf deflection/130 kgf deflection) is from 3.30 to 3.70.

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