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(54) SHUTTLECOCK ARTIFICIAL FEATHER AND BADMINTON SHUTTLECOCK

(57) The present invention addresses the problem of providing: a shuttlecock artificial feather (1) including a rachis that is lightweight and that has a high rigidity; and a badminton shuttlecock (20) including the shuttlecock artificial feather. The shuttlecock artificial feather according to the present invention includes: a vane portion (3); and a rachis portion (5) fastened to the vane portion. The rachis portion includes: a core portion region (11) having pores; and an outer layer region (13) coating the core portion region and having a solid structure.

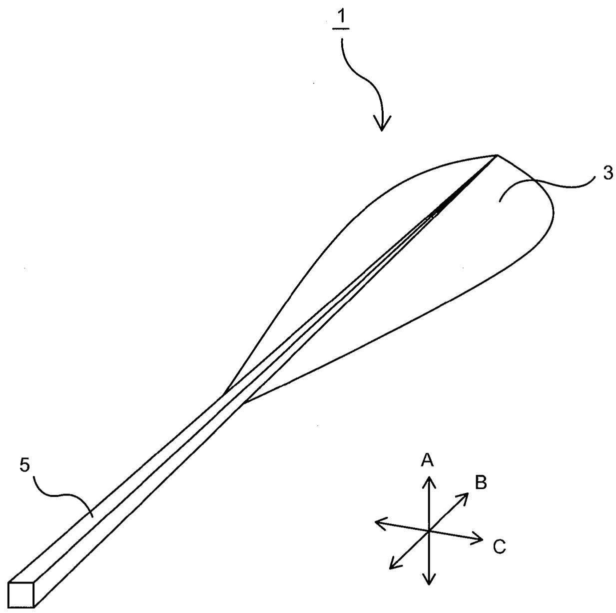

Fig. 1

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Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to: a shuttlecock artificial feather; and a badminton shuttlecock obtained by using the shuttlecock artificial feather. More specifically, the present invention relates to a technology for modifying a rachis portion of the badminton shuttlecock.

Description of the Background Art

[0002] A majority of badminton shuttlecocks are obtained by: inserting 16 natural feathers collected, in general, from a waterfowl or the like into a base that is made of a cork or a urethane and that has a surface on which a cover made of rubber is pasted; fixing the feathers by means of an adhesive; and joining together the feathers by using yarns. Each natural feather has a low specific gravity and is very lightweight. In addition, a rachis of the natural feather has a high rigidity and a high resilience. Therefore, a badminton shuttlecock obtained by using the natural feathers has distinctive flight performance and provides comfortable feel at hitting.

[0003] However, the natural feathers are expensive, the resources thereof are unstable, and there is also variation in performance among the natural feathers. Considering this, development has been progressing regarding artificial feathers to which characteristics similar to the characteristics of the natural feathers are imparted.

[0004] For example, Japanese Laid-Open Patent Publication No. 2015-073782 discloses an artificial feather including: a vane portion; and a rachis portion obtained by injection molding of resin pellets with which thermally-expandable microcapsules have been mixed in a weight proportion of 1 to 10%. The rachis portion includes: a core portion having a foamed structure; and a surface layer portion coating a side surface of the core portion. Japanese Laid-Open Patent Publication No. 2015-073782 further indicates that each thermally-expandable microcapsule is obtained by encapsulating, in a shell formed from a thermoplastic polymeric resin and having a film thickness of about 2 to 15 μm, an expanding agent formed from an aliphatic hydrocarbon or the like.

[0005] Chinese Patent Application Publication No. 101491730 discloses an artificial feather for a badminton shuttlecock, the artificial feather including a rachis and a vane. The rachis has a structure including a core portion and a coating layer. The coating layer is formed from polypropylene. The core portion is formed from a polyurethane foaming material. Chinese Patent Application Publication No. 101491730 further discloses a method for manufacturing the rachis, the method including: first making, from polypropylene, a hollow tubule (coating layer) having a diameter smaller than 1.5 mm and a wall thickness of about 0.2 mm; and then injecting a polyurethane material into a bore of the tubule; and foaming the polyurethane material, to make a core portion.

SUMMARY OF THE INVENTION

[0006] The present invention addresses the problem of providing: a shuttlecock artificial feather including a rachis that is lightweight and that has a high rigidity; and a badminton shuttlecock including the shuttlecock artificial feather.

[0007] A shuttlecock artificial feather according to the present invention having solved the aforementioned problem includes: a vane portion; and a rachis portion fastened to the vane portion, wherein the rachis portion includes a core portion region having pores, and an outer layer region coating the core portion region and having a solid structure.

[0008] The rachis portion of the shuttlecock artificial feather according to the present invention is characterized by including: the core portion region having the pores; and the outer layer region coating the core portion region and having the solid structure. Since the outer layer region has the solid structure and the rachis portion includes the core portion region coated by the outer layer region and having the pores, the rachis portion has a structure similar to the structure of a rachis of a natural feather. Consequently, a shuttlecock artificial feather that is lightweight and that has a high rigidity, is obtained.

[0009] The present invention also encompasses a method for manufacturing a shuttlecock artificial feather. The method for manufacturing a shuttlecock artificial feather according to the present invention includes the steps of: melt-kneading a rachis resin composition; introducing a foaming agent as a supercritical fluid to the melted rachis resin composition, to make a melt-kneaded product; injecting the melt-kneaded product into a mold; reducing at least one of a pressure and a temperature of the foaming agent to be lower than a critical point of the foaming agent so that the resin composition is foamed, to make a rachis portion; and fastening the rachis portion and a vane portion to each other.

[0010] The present invention leads to obtainment of: a shuttlecock artificial feather including a rachis that is lightweight and that has a high rigidity; and a badminton shuttlecock obtained by using the shuttlecock artificial feather.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011]

FIG. 1 is a perspective view of an example of an artificial feather for a badminton shuttlecock according to the present invention;

FIGS. 2(a) and (b) are diagrams for explaining an example of the artificial feather for a badminton shuttlecock according to the present invention;

FIG. 3 is a cross-sectional view of an example of a rachis portion of the artificial feather according to the present invention;

FIGS. 4(a) and (b) are diagrams for explaining an example of the rachis portion of the artificial feather according to the present invention;

FIGS. 5(a) and (b) are diagrams for explaining an example of the rachis portion of the artificial feather according to the present invention; and

FIG. 6 is a front view of an example of a badminton shuttlecock according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0012] A shuttlecock artificial feather according to the present invention includes: a vane portion; and a rachis portion fastened to the vane portion. The rachis portion is characterized by including: a core portion region having pores; and an outer layer region coating the core portion region and having a solid structure.

[0013] In the shuttlecock artificial feather according to the present invention, the vane portion has a planar shape that resembles the shape of a vane of a natural feather. In the shuttlecock artificial feather according to the present invention, a normal direction to a plane of the vane portion is defined as an up-down direction, and a direction orthogonal to the up-down direction and a rachis direction is defined as a width direction. The up-down direction of the rachis portion may be referred to as a front-back direction relative to the plane of the vane portion.

[0014] The rachis portion has a leading end and a tail end. The leading end side of the rachis portion is fastened to the vane portion. The tail end side of the rachis portion is embedded in a base portion of a shuttlecock. The rachis portion includes: a fastened-to-vane portion fastened to the vane portion; a root portion to be embedded in a base portion of a shuttlecock; and an intermediate portion located between the fastened-to-vane portion and the root portion.

[0015] A cross-sectional shape, of the rachis portion, that is perpendicular to the axial direction thereof is not particularly limited, and examples of the cross-sectional shape include a circular shape, a substantially circular shape, an elliptic shape, a substantially elliptic shape, a polygonal shape, and the like. Among these cross-sectional shapes, a polygonal shape is preferable, and a rectangular shape is more preferable.

[0016] The rachis portion has a cross section perpendicular to the rachis direction. In the cross section, the core portion having the pores is present at a center portion, and the outer layer region having the solid structure is provided at a periphery that encloses the upper, lower, left, and right sides of the core portion.

[0017] Examples of the manner of fastening the rachis portion and the vane portion to each other can include: a manner in which the lower surface of the rachis portion and the front surface of the vane portion are fastened to each other; a manner in which the upper surface of the rachis portion and the back surface of the vane portion are fastened to each other; a manner in which the vane portion is composed of two sheets and the fastened-to-vane portion is interposed between the two vane portions; and the like. In the present invention, it is preferable that the lower surface of the rachis portion and the front surface of the vane portion are fastened to each other.

[0018] The rachis portion preferably includes, over the entirety in the axial direction of the rachis portion (over the entire length of the rachis portion from the leading end to the tail end), the core portion region having the pores and the outer layer region coating the core portion region and having the solid structure.

[0019] The flexural modulus of elasticity of the outer layer region is preferably not lower than 1.5 GPa, more preferably not lower than 3 GPa, and further preferably not lower than 4.5 GPa. Meanwhile, the flexural modulus of elasticity is preferably not higher than 12 GPa, more preferably not higher than 11 GPa, and further preferably not higher than 10 GPa. This is because, if the flexural modulus of elasticity of the outer layer region falls within the aforementioned range, the rigidity of the rachis portion is increased, and the durability thereof is improved.

[0020] The thickness of the outer layer region is preferably not smaller than 0.05 mm, more preferably not smaller than 0.10 mm, and further preferably not smaller than 0.15 mm. Meanwhile, the thickness is preferably not larger than 0.60 mm, more preferably not larger than 0.50 mm, and further preferably not larger than 0.40 mm.

[0021] The length of the rachis portion is preferably not smaller than 67 mm and more preferably not smaller than 70 mm. Meanwhile, the length is preferably not larger than 85 mm, more preferably not larger than 82 mm, further preferably not larger than 80 mm, and particularly preferably not larger than 76 mm. The length of a shuttlecock from a base portion thereof to the leading end of each artificial feather should be within a range of 62 mm to 70 mm according to sporting regulations.

[0022] Although the length of the root portion (the portion to be inserted into a base portion) of the rachis portion is not particularly limited, the length is preferably not smaller than 5 mm and more preferably not smaller than 6 mm. Meanwhile, the length is preferably not larger than 15 mm and more preferably 13 mm.

[0023] The length of the fastened-to-vane portion from the leading end of the rachis portion is preferably not smaller than 35 mm and more preferably not smaller than 36 mm. Meanwhile, the length is preferably not larger than 41 mm and preferably not larger than 42 mm.

[0024] The width of the rachis portion is not particularly limited, and examples of the form thereof regarding the width can include: a tapered form in which the width gradually increases from the leading end to the tail end; a form in which the width is fixed from the leading end to the tail end; a form in which the rachis is tapered from the leading end to the root portion thereof, and the width of the root portion is fixed; and the like.

[0025] The height in the up-down direction of the rachis portion is not particularly limited, and examples of the form thereof regarding the height can include: a form in which the height gradually increases from the leading end to the tail end; a form in which the height is fixed from the leading end to the tail end; a form in which the height gradually increases from the leading end to the root portion of the rachis, and the height of the root portion is fixed; and the like.

[0026] The height H1 of the leading end of the rachis portion is preferably not lower than 1.2 mm, more preferably not lower than 1.5 mm, and further preferably not lower than 1.8 mm. Meanwhile, the height H1 is preferably not higher than 2.8 mm, more preferably not higher than 2.6 mm, and further preferably not higher than 2.4 mm.

[0027] The width W1 of the leading end of the rachis portion is preferably not smaller than 0.6 mm, more preferably not smaller than 0.8 mm, and further preferably not smaller than 1.0 mm. Meanwhile, the width W1 is preferably not larger than 2 mm, more preferably not larger than 1.8 mm, and further preferably not larger than 1.5 mm.

[0028] The height H2 of the tail end of the rachis portion is preferably not lower than 1.6 mm, more preferably not lower than 1.8 mm, and further preferably not lower than 2 mm. Meanwhile, the height H2 is preferably not higher than 3.5 mm, more preferably not higher than 3.3 mm, and further preferably not higher than 3 mm.

[0029] The width W2 of the tail end of the rachis portion is preferably not smaller than 1 mm, more preferably not smaller than 1.2 mm, and further preferably not smaller than 1.4 mm. Meanwhile, the width W2 is preferably not larger than 2.4 mm, more preferably not larger than 2.2 mm, and further preferably not larger than 2.0 mm.

[0030] The lower surface side of the rachis portion is preferably fastened to the vane portion. The lower surface of the rachis portion is preferably provided with a tilted surface. Specifically, the lower surface of the rachis portion is preferably slanted relative to the upper surface thereof such that the distance between the upper surface and the lower surface of the rachis portion gradually increases from the leading end toward the tail end. The tilted surface may be provided from the leading end to the tail end of the rachis portion or may be provided from the leading end of the rachis portion to any location on the rachis portion. For example, the tilted surface is preferably provided from the leading end to the root portion of the rachis portion.

[0031] In a preferable form of the present invention, the height H1 in the up-down direction of the leading end of the rachis is preferably lower than the height H2 in the up-down direction of the tail end thereof. This enables reduction in the air resistance of the rachis portion.

[0032] The core portion region of the rachis portion has pores. Although the pores may be independent pores or continuous pores, the pores are preferably independent pores. The pores are preferably formed by a foaming process. The diameter of each pore is preferably not larger than 1000 μm, more preferably not larger than 500 μm, and further preferably not larger than 100 μm.

[0033] Although the thickness of the core portion region is not particularly limited, the thickness is preferably not smaller than 1.0 mm, more preferably not smaller than 1.2 mm, and further preferably not smaller than 1.4 mm. Meanwhile, the thickness is preferably not larger than 2.4 mm, more preferably not larger than 2.2 mm, and further preferably not larger than 2.0 mm.

[0034] The density of the rachis portion is preferably not lower than 0.52 g/cm^3, more preferably not lower than 0.54 g/cm^3, and further preferably not lower than 0.56 g/cm^3. Meanwhile, the density is preferably not higher than 1.00 g/cm^3, more preferably not higher than 0.90 g/cm^3, and further preferably not higher than 0.85 g/cm^3. If the density of the rachis portion is lower than 0.52 g/cm^3, the strength thereof decreases, whereby a badminton shuttlecock having excellent durability may not be obtained. Meanwhile, if the density of the rachis portion is higher than 1.00 g/cm^3, the obtained rachis becomes heavy, whereby a badminton shuttlecock that has excellent flight performance and that provides excellent feel at hitting may not be obtained.

[0035] It is also preferable that the density of the rachis portion varies in the axial direction of the rachis portion. If the density is set as appropriate, optimization can be performed regarding the rigidity and weight reduction of the rachis portion. For example, the density D1 of the fastened-to-vane portion fastened to the vane portion is preferably lower than the density D2 of the root portion. This is for reducing the weight of the fastened-to-vane portion.

[0036] The flexural modulus of elasticity of a foam-molded article of a rachis resin composition that forms the rachis portion is preferably not lower than 1.0 GPa, more preferably not lower than 1.2 GPa, and further preferably not lower than 1.5 GPa. This is because, if the flexural modulus of elasticity of the foam-molded article of the rachis resin composition that forms the rachis portion is not lower than 1.0 GPa, a rachis having a high strength is obtained.

[0037] The product of the flexural modulus of elasticity (GPa) and the thickness (mm) of the foam-molded article of the rachis resin composition that forms the rachis portion is preferably not smaller than 4.0, more preferably not smaller than 4.2, and further preferably not smaller than 4.5. This is because, if the product of the flexural modulus of elasticity (GPa) and the thickness (mm) of the foam-molded article of the rachis resin composition that forms the rachis portion is not smaller than 4.0, a rachis portion having a high strength is obtained.

[0038] The density of the foam-molded article of the rachis resin composition that forms the rachis portion is preferably not lower than 0.52 g/cm^3, more preferably not lower than 0.54 g/cm^3, and further preferably not lower than 0.56 g/cm^3. Meanwhile, the density is preferably not higher than 1.00 g/cm^3, more preferably not higher than 0.90 g/cm^3, and further preferably not higher than 0.85 g/cm^3. If the density of the foam-molded article is lower than 0.52 g/cm^3, the strength thereof decreases, whereby a badminton shuttlecock having excellent durability may not be obtained. Meanwhile, if the density of the foam-molded article is higher than 1.00 g/cm^3, the obtained rachis becomes heavy, whereby a badminton shuttlecock that has excellent flight performance and that provides excellent feel at hitting may not be obtained.

[0039] In the shuttlecock artificial feather according to the present invention, the core portion region and the outer layer region are preferably formed from a single resin composition. If the core portion region and the outer layer region are formed substantially from a single resin composition, a peel strength at the interface between the core portion region and the outer layer region is increased. As a result, the durability of the entirety of the rachis portion is increased.

[0040] More specifically, it is preferable that: the core portion region, of the rachis portion, which has the pores is formed by foaming the single resin composition; and the outer layer region is formed without foaming the single resin composition. The rachis portion of the shuttlecock artificial feather according to the present invention is preferably formed by supercritical foam-molding described later.

[0041] The rachis portion is formed from a rachis resin composition that contains a resin component. The resin component is not particularly limited, and examples thereof include polybutylene terephthalate (PBT), polyphenylene ether (PPE), polyethylene terephthalate (PET), polyethylene (PE), polypropylene (PP), polysulfone (PSF), polyether sulfone (PES), polyphenylene sulfide (PPS), polyarylate (PAR), polyamidimide (PAI), polyetherimide (PEI), polyether ether ketone (PEEK), polyimide (PI), polytetrafluoroethylene (PTFE), polyaminobismaleimide (PABM), polybisamide triazole, polyphenylene oxide (PPO), polyacetal, polycarbonate (PC), acrylonitrile-butadiene-styrene copolymer (ABS), acrylonitrile-styrene copolymer (AS), and the like. Among these resin components, a polyamide, polypropylene, acrylonitrile-butadiene-styrene copolymer (ABS), and polycarbonate are preferable as the resin component. These resin components may be used singly, or two or more types of these resin components may be used in combination.

[0042] Examples of the polyamide include: aliphatic polyamides such as polyamide 6, polyamide 11, polyamide 12, polyamide 66, polyamide 610, and polyamide 612; semi-aromatic polyamides such as polyamide 6T, polyamide 61, polyamide 9T, and polyamide M5T; and aromatic polyamides such as poly-p-phenylene terephthalamide and poly-m-phenylene isophthalamide. These polyamides may be used singly, or two or more types of these polyamides may be used in combination. Among these polyamides, aliphatic polyamides such as polyamide 6, polyamide 66, polyamide 11, and polyamide 12 are suitable from the viewpoint of processability and durability.

[0043] The rachis portion of the artificial feather according to the present invention is preferably formed from a rachis resin composition that contains acrylonitrile-butadiene-styrene copolymer (ABS) and polycarbonate (PC) as resin components. This is because the rachis resin composition that contains acrylonitrile-butadiene-styrene copolymer (ABS) and polycarbonate (PC) has a high compatibility with a foaming agent so that a further favorable foamed state is obtained. The acrylonitrile-butadiene-styrene copolymer (ABS) content of the entire resin component is preferably not lower than 20% by mass, more preferably not lower than 25% by mass, and further preferably not lower than 30% by mass. Meanwhile, the acrylonitrile-butadiene-styrene copolymer (ABS) content is preferably not higher than 50% by mass, more preferably not higher than 45% by mass, and further preferably not higher than 40% by mass. The polycarbonate content of the entire resin component is preferably not lower than 30% by mass, more preferably not lower than 35% by mass, and further preferably not lower than 40% by mass. Meanwhile, the polycarbonate content is preferably not higher than 60% by mass, more preferably not higher than 55% by mass, and further preferably not higher than 50% by mass.

[0044] The rachis resin composition that contains acrylonitrile-butadiene-styrene copolymer (ABS) and polycarbonate (PC) may further contain a modifier. The modifier content is preferably not higher than 15% by mass. Examples of the modifier can include fluidity modifiers, compatibilizers, flame retarders, ultraviolet absorbing agents, antioxidants, and the like.

[0045] The acrylonitrile-butadiene-styrene copolymer (ABS) content, the polycarbonate (PC) content, and the modifier content only have to be determined as appropriate from within the aforementioned ranges such that the total of the contents is 100% by mass.

[0046] The rachis resin composition may contain a reinforcing fiber. If the reinforcing fiber is contained, mechanical physical properties of the obtained rachis are improved. Examples of the reinforcing fiber include inorganic fibers, organic fibers, metal fibers, hybrid reinforcing fibers in which these fibers are combined, and the like. One or more types of these reinforcing fibers may be used.

[0047] Examples of the inorganic fibers include carbon fibers, alumina fibers, boron fibers, glass fibers, and the like. Examples of the organic fibers include aramid fibers, high-density polyethylene fibers, cellulose fibers, other generally-used nylon fibers, polyester fibers, and the like. Examples of the metal fibers include fibers of stainless steel, iron, and the like. Examples of the metal fibers further include carbon-coated metal fibers obtained by coating metal fibers with carbon.

[0048] The rachis resin composition used in the present invention preferably contains at least one type of reinforcing fiber selected from the group consisting of glass fibers, carbon fibers, and aramid fibers.

[0049] As the resin component of the rachis resin composition, a fiber-reinforced resin in which the reinforcing fiber has been blended in the resin in advance is preferably used. Examples of the fiber-reinforced resin include short-fiber-reinforced resins and long-fiber-reinforced resins. In the case of using a fiber-reinforced resin, the reinforcing fiber content of the fiber-reinforced resin is preferably not lower than 10% by mass, more preferably not lower than 15% by mass, and further preferably not lower than 20% by mass. Meanwhile, the reinforcing fiber content is preferably not higher than 60% by mass, more preferably not higher than 55% by mass, and further preferably not higher than 50% by mass.

[0050] For example, in the cases of glass-fiber-reinforced resins, a glass-short-fiber-reinforced resin is obtained by kneading the resin and glass-chopped strands having fiber lengths of about 5 mm and making the kneaded product into pellets. A glass-long-fiber-reinforced resin is obtained by: introducing a glass fiber in the form of a roving into an impregnation die so as to perform uniform impregnation with melted thermoplastic resin between filaments of the roving; and then cutting the impregnated roving into required lengths (ordinarily, 5 to 20 mm), to obtain pellets.

[0051] The present invention also encompasses a method for manufacturing the shuttlecock artificial feather. The method for manufacturing the shuttlecock artificial feather according to the present invention is characterized by including the steps of: melt-kneading a rachis resin composition; introducing a foaming agent as a supercritical fluid to the melted rachis resin composition, to make a melt-kneaded product; injecting the melt-kneaded product into a mold; reducing at least one of a pressure and a temperature of the foaming agent to be lower than a critical point of the foaming agent so that the resin composition is foamed, to make a rachis portion; and fastening the rachis portion and a vane portion to each other. In the present invention, the rachis portion is preferably molded by a supercritical foam-molding method. Employment of the supercritical foam-molding method makes it possible to suitably manufacture a rachis portion including: a core portion region having pores; and an outer layer region coating the core portion region and having a solid structure.

[0052] The method for molding the rachis portion by supercritical foam-molding includes the steps of: melt-kneading a rachis resin composition; introducing a foaming agent as a supercritical fluid to the melted rachis resin composition, to make a melt-kneaded product; injecting the melt-kneaded product into a mold; and reducing at least one of a pressure and a temperature of the foaming agent to be lower than a critical point of the foaming agent so that the resin composition is foamed.

[0053] The supercritical foam-molding can be performed by using, for example, an injection molding machine and a supercritical fluid introducing device for introducing a supercritical fluid into a cylinder of the injection molding machine. Hereinafter, a specific example of the supercritical foam-molding will be described.

[0054] First, the rachis resin composition is injected into the cylinder of the injection molding machine, and heated and kneaded in the cylinder so that the rachis resin composition is melted.

[0055] A setting temperature in the cylinder is not particularly limited and only has to be selected as appropriate according to the type of the rachis resin composition, as long as the setting temperature allows the rachis resin composition to melt. The setting temperature in the cylinder is preferably not lower than 170°C and more preferably not lower than 200°C. Meanwhile, the setting temperature is preferably not higher than 400°C and more preferably not higher than 300°C.

[0056] A heating and kneading time in the cylinder only has to be set as appropriate according to the type, the injection amount, and the like of the rachis resin composition. The heating and kneading time in the cylinder is preferably not shorter than 2 minutes and more preferably not shorter than 3 minutes. Meanwhile, the heating and kneading time is preferably not longer than 10 minutes and more preferably not longer than 8 minutes.

[0057] Subsequently, a foaming agent as a supercritical fluid supplied from the supercritical fluid introducing device is introduced into the cylinder of the injection molding machine and melt-kneaded with the rachis resin composition.

[0058] Here, the "supercritical fluid" is a term indicating a state, of a substance, that is none of gas, liquid, and solid states and that is assumed by the substance under a condition of being not lower than a specific temperature and a specific pressure (critical points). The critical points which are a specific temperature and a specific pressure are determined according to the type of the substance. A substance as a supercritical fluid has a higher seepage force (solubility) into melted resin than the substance in a gas state or a liquid state, and thus can be uniformly dispersed in the melted resin.

[0059] As the foaming agent as the supercritical fluid, for example, an inert gas such as carbon dioxide, nitrogen, or helium, air, or the like can be used. Among these foaming agents, nitrogen (critical point temperature: -147°C, critical point pressure: 3.4 MPa) allows adjustment for the supercritical fluid merely by controlling a pressure, and is easily handled. Thus, nitrogen is particularly preferable.

[0060] The introduction amount of the foaming agent as the supercritical fluid per 100 parts by mass of the resin component of the rachis resin composition is preferably not smaller than 0.1 parts by mass, more preferably not smaller than 0.2 parts by mass, and further preferably not smaller than 0.3 parts by mass. Meanwhile, the introduction amount is preferably not larger than 3 parts by mass, more preferably not larger than 1.5 parts by mass, and further preferably not larger than 1 part by mass. If the introduction amount of the foaming agent as the supercritical fluid is smaller than 0.1 parts by mass, foaming of the resin composition may not sufficiently progress. Meanwhile, if the introduction amount of the foaming agent as the supercritical fluid is larger than 3 parts by mass, a poor appearance may result from unsatisfactory melting of the supercritical fluid into the resin.

[0061] A kneading time for the foaming agent as the supercritical fluid and the resin composition which have been introduced into the cylinder of the injection molding machine only has to be a time that allows the resin composition to be sufficiently impregnated with the foaming agent as the supercritical fluid. Ordinarily, the kneading time is preferably 1 minute to 0.15 hours.

[0062] Next, the melt-kneaded product made from the foaming agent as the supercritical fluid and the resin composition is injected into a mold of the injection molding machine. The injection speed of the melt-kneaded product is preferably not lower than 20 mm/second, more preferably not lower than 50 mm/second, and further preferably not lower than 80 mm/second. Meanwhile, the injection speed is preferably not higher than 300 mm/second, more preferably not higher than 280 mm/second, and further preferably not higher than 250 mm/second. If the injection speed of the melt-kneaded product is lower than 20 mm/second, a flow mark may be generated on a surface of the molded article. Meanwhile, if the injection speed of the melt-kneaded product is higher than 300 mm/second, shear fracture of air bubbles may occur.

[0063] After the melt-kneaded product made from the foaming agent as the supercritical fluid and the resin composition is injected into the mold, at least one of the pressure and the temperature of the foaming agent as the supercritical fluid is reduced to be lower than the critical point of the supercritical fluid in the mold. Consequently, the foaming agent as the supercritical fluid with which the rachis resin composition has been impregnated is changed into gas to have an increased volume, and foaming occurs inside the rachis resin composition. Further, the melted rachis resin composition has a surface layer in contact with the mold (the setting temperature of the mold is lower than the temperature of the melted resin composition), and the surface layer is formed as a skin layer (solid layer containing substantially no foam). Then, the rachis resin composition in the mold is cooled and solidified, whereby a foam-molded article having a solid structure on the surface layer portion and a foamed structure on the core portion, is obtained.

[0064] The method for reducing at least one of the pressure and the temperature of the foaming agent as the supercritical fluid to be lower than the critical point of the supercritical fluid, is not particularly limited. Examples of the method include a short-shot method (a method in which the mold is filled with the resin having an amount smaller than the mold capacity, and the filling is completed by generation of air bubbles), a full-shot method (a method in which the mold is filled with the resin having an amount equal to the mold capacity, and generation and expansion of air bubbles make up for the portion that has thermally contracted after molding), a core-back method (a method in which at least a part of the mold is moved backward so that the mold capacity is increased), and the like. The core-back method is preferable from the viewpoint of being able to obtain a high expansion ratio with uniform foaming.

[0065] In the case of employing the core-back method, a standby time taken until core-back is started after the melt-kneaded product made from the foaming agent as the supercritical fluid and the resin composition has been injected into the mold, is preferably not shorter than 0.1 seconds, more preferably not shorter than 0.2 seconds, and further preferably not shorter than 0.3 seconds. Meanwhile, the standby time is preferably not longer than 3 seconds, more preferably not longer than 2.5 seconds, and further preferably not longer than 2 seconds. If the standby time taken until core-back is started is set to fall within the aforementioned range, the skin layer can be formed, and concurrently, the temperature of the resin can be kept within a temperature range that is optimal for foaming.

[0066] A core-back time (the time taken to expand the mold capacity) is preferably not shorter than 0.1 seconds, more preferably not shorter than 0.2 seconds, and further preferably not shorter than 0.4 seconds. Meanwhile, the core-back time is preferably not longer than 3 seconds, more preferably not longer than 2 seconds, and further preferably not longer than 1 second. If the core-back time is set to fall within the aforementioned range, the temperature of the resin can be kept within a temperature range that is optimal for foaming.

[0067] A setting temperature in the mold is preferably not lower than 30°C, more preferably not lower than 40°C, and further preferably not lower than 50°C. Meanwhile, the setting temperature is preferably not higher than 100°C, more preferably not higher than 90°C, and further preferably not higher than 80°C. If the setting temperature in the mold is set to fall within this range, the thickness of the skin layer can be controlled. Further, the rachis portion is preferably made under the same condition as a core-back molding condition in which, when the foam-molded article is molded from the rachis resin composition, the product of the flexural modulus of elasticity (GPa) and the thickness (mm) of the foam-molded article is not smaller than 4.0 and the density of the foam-molded article is not higher than 1.00 g/cm^3.

[0068] The expansion ratio of the entirety of the rachis portion is preferably not lower than 1.2 times, more preferably not lower than 1.3 times, and further preferably not lower than 1.5 times. Meanwhile, the expansion ratio is preferably not higher than 2.4 times, more preferably not higher than 2.2 times, and further preferably not higher than 2.0 times. If the expansion ratio of the entirety of the rachis portion is lower than 1.2 times, the obtained rachis becomes heavy, whereby a badminton shuttlecock that has excellent flight performance and that provides excellent feel at hitting may not be obtained. Meanwhile, if the expansion ratio of the entirety of the rachis portion is higher than 2.4 times, the strength of the obtained rachis decreases, whereby a badminton shuttlecock having excellent durability may not be obtained.

[0069] The expansion ratio of the rachis portion is also preferably caused to vary depending on parts of the rachis portion. If the expansion ratio is caused to vary depending on parts of the rachis portion, the density of the rachis portion can be caused to vary.

[0070] The expansion ratio of each of the leading end and the tail end of the rachis portion is preferably not lower than 1.2 times, more preferably not lower than 1.3 times, and further preferably not lower than 1.5 times. Meanwhile, the expansion ratio is preferably not higher than 2.4 times, more preferably not higher than 2.2 times, and further preferably not higher than 2.0 times. If the expansion ratio of each of the leading end and the tail end of the rachis portion is lower than 1.2 times, the obtained rachis becomes heavy, whereby a badminton shuttlecock that has excellent flight performance and that provides excellent feel at hitting may not be obtained. Meanwhile, if the expansion ratio of each of the leading end and the tail end of the rachis portion is higher than 2.4 times, the strength of the obtained rachis decreases, whereby a badminton shuttlecock having excellent durability may not be obtained.

[0071] For example, the expansion ratio of the leading end of the rachis portion is preferably set to be higher than the expansion ratio of the tail end of the rachis portion, and the expansion ratio of the fastened-to-vane portion of the rachis portion is preferably set to be higher than the expansion ratio of the root portion of the rachis portion. By these settings, the density D1 of the fastened-to-vane portion of the rachis portion becomes lower than the density D2 of the root portion of the rachis portion.

[0072] The rachis portion obtained as described above is attached to the vane portion. The vane portion may be made by injection molding using a vane portion resin composition, or may be made by cutting a resin film or a nonwoven fabric. The vane portion of the shuttlecock artificial feather according to the present invention is preferably made by cutting a resin film or a nonwoven fabric.

[0073] The rachis portion can be fastened to the vane portion by means of, for example, an adhesive or the like.

[0074] Hereinafter, a form of the shuttlecock artificial feather according to the present invention will be described with reference to the drawings. However, the form of the shuttlecock artificial feather according to the present invention is not limited to the form shown in the drawings.

[0075] FIG. 1 is a perspective view for explaining the structure of the shuttlecock artificial feather. A shuttlecock artificial feather 1 includes: a vane portion 3; and a rachis portion 5 fastened to the vane portion 3. The vane portion 3 has a planar shape, and the arrow A indicates a normal direction (up-down direction) to a plane of the vane portion 3. The arrow B indicates a rachis direction in which the rachis extends. The arrow C is the width direction of the artificial feather and is orthogonal to the normal direction A (up-down direction) and the rachis direction B.

[0076] FIGS. 2(a) and (b) are diagrams for explaining an example of the shuttlecock artificial feather according to the present invention. FIG. 2(a) is a plan view of a front surface of the artificial feather, and FIG. 2(b) is a plan view of a back surface thereof. Here, when the artificial feather is attached to a shuttlecock, the front surface is a surface located on the outer side of the shuttlecock, and the back surface is a surface located on the inner side of the shuttlecock.

[0077] The rachis portion 5 is fastened to substantially the center in the width direction of the vane portion 3. The rachis portion 5 has a leading end 7 and a tail end 9. The rachis portion 5 includes: a fastened-to-vane portion 5a fastened to the vane portion 3; a root portion 5c to be embedded in a base of a shuttlecock; and an intermediate portion 5b located between the fastened-to-vane portion 5a and the root portion 5c. The rachis portion 5 is preferably fastened to the vane portion such that the leading end 7 of the rachis portion 5 and a leading end of the vane portion 3 coincide with each other.

[0078] FIG. 3 is a cross-sectional view, at A-A, of the artificial feather in FIG. 2(a). In this form, the cross section of the rachis portion 5 has a rectangular shape. The rachis portion 5 includes: a core portion region 11 having pores; and an outer layer region 13 coating the core portion region 11 and having a solid structure. In the cross section of the rachis portion 5, the core portion 11 having the pores is present at substantially the center, and the outer layer region 13 coating the periphery of the core portion 11 is present.

[0079] The outer layer region 13 of the fastened-to-vane portion 5a is fastened to the front surface of the vane portion 3. The outer layer region 13 is made from a material having a high modulus of flexural rigidity, and thus the rachis portion 5 is less likely to be damaged upon an impact from a racket.

[0080] FIGS. 4(a) and (b) are diagrams for explaining an example of the rachis portion 5 of the artificial feather according to the present invention. FIG. 4(a) is a plan view, and FIG. 4(b) is a cross-sectional view at B-B in FIG. 4(a). In the form shown in FIGS. 4(a) and (b), the width of the rachis portion 5 is fixed from leading end 7 to the tail end 9.

[0081] In FIG. 4(b), the rachis portion 5 includes: the core portion region 11 having the pores; and an upper outer layer region 13a and a lower outer layer region 13b coating the core portion region 11 and having solid structures. The rachis portion 5 includes these regions over the entirety in the axial direction B of the rachis portion 5, i.e., over the entire length thereof from the leading end 7 to the tail end 9. The thickness of each of the outer layer regions 13a and 13b is substantially fixed over the entire length from the leading end 7 to the tail end 9. Each of the outer layer regions 13a and 13b is made from a material having a high modulus of flexural rigidity, and thus the rachis portion 5 is less likely to be damaged upon an impact from a racket.

[0082] In FIG. 4(b), the height H1 of the leading end of the rachis portion 5 is lower than the height H2 of the tail end of the rachis portion. This enables reduction in the air resistance of the rachis portion. The height in the up-down direction of the rachis portion 5 gradually increases from the leading end 7 to the root portion 5c of the rachis, and the height of the root portion 5c is fixed.

[0083] The structure of the rachis portion such as one shown in FIG. 4(b) is made by, for example, foaming the rachis resin composition through supercritical foam-molding.

[0084] The lower outer layer region 13b of the fastened-to-vane portion 5a is fastened to the vane portion 3. The lower surface of the rachis portion 5 is provided with a tilted surface 6. The tilted surface 6 is provided from the leading end 7 to the root portion 5c of the rachis portion.

[0085] The density D1 of the fastened-to-vane portion 5a is preferably lower than the density D2 of the root portion 5c. This is for reducing the weight of the fastened-to-vane portion.

[0086] FIGS. 5(a) and (b) are diagrams for explaining another preferable form of the rachis portion 5 of the artificial feather according to the present invention. FIG. 5(a) is a plan view, and FIG. 5(b) is a cross-sectional view at C-C in FIG. 5(a).

[0087] In FIG. 5(a), the width W2 of the tail end 9 of the rachis portion 5 is larger than the width W1 of the leading end 7 thereof. The rachis portion is tapered such that the width thereof increases from the leading end 7 to the root portion 5c of the rachis, and the width of the root portion 5c is fixed.

[0088] In FIG. 5(b), the rachis portion 5 includes: the core portion region 11 having the pores; and the upper outer layer region 13a and the lower outer layer region 13b coating the core portion region 11 and having solid structures. The rachis portion 5 includes these regions over the entirety in the axial direction B of the rachis portion 5, i.e., over the entire length thereof from the leading end 7 to the tail end 9. The thickness of each of the outer layer regions 13a and 13b is substantially fixed over the entire length from the leading end 7 to the tail end 9. Each of the outer layer regions 13a and 13b is made from a material having a high modulus of flexural rigidity, and thus the rachis portion 5 is less likely to be damaged upon an impact from a racket.

[0089] In FIG. 5(b), the height H1 of the leading end of the rachis portion 5 is lower than the height H2 of the tail end of the rachis portion. This enables reduction in the air resistance of the rachis portion. The height in the up-down direction of the rachis portion 5 gradually increases from the leading end 7 to the root portion 5c of the rachis portion, and the height of the root portion 5c is fixed.

[0090] The structure of the rachis portion such as one shown in FIG. 5(b) is made by, for example, foaming the rachis resin composition through supercritical foam-molding.

[0091] The upper surface of the rachis portion 5 is a flat surface. The lower surface of the rachis portion 5 is provided with a tilted surface 6. The tilted surface 6 is provided from the leading end to the root portion 5c of the rachis portion 5. The lower outer layer region 13b of the fastened-to-vane portion 5a is fastened to the vane portion 3.

[0092] The density D1 of the fastened-to-vane portion 5a is preferably lower than the density D2 of the root portion 5c. This is for reducing the weight of the fastened-to-vane portion.

[0093] The present invention encompasses a badminton shuttlecock including the shuttlecock artificial feather according to the present invention. Specifically, the badminton shuttlecock according to the present invention is characterized by including: a hemispherical base portion; and a plurality of the shuttlecock artificial feathers according to the present invention arranged in an annular pattern on the base portion.

[0094] FIG. 6 is a diagram for explaining an example of the badminton shuttlecock according to the present invention. A badminton shuttlecock 20 includes: a base portion 21; and artificial feathers 1 provided to the base portion 21. As a material of the base portion 21, for example, a natural material such as a cork can be used.

[0095] The base portion has a hemispherical shape and has a circular flat upper surface. The base portion has a diameter of 25 mm to 28 mm and is set to have a round bottom. The plurality of artificial feathers are arranged in an annular pattern along the circumference of the upper surface of the base portion. The base portion 21 is made of, for example, a cork including: a hemispherical portion 21a having an outer diameter of about 26 mm; and a columnar portion 21b having an outer diameter of 26 mm and a length of 10 mm. The artificial feathers, the number of which is 16, are inserted at equal intervals along the circumference, of a flat surface portion of the columnar portion, that has an inner diameter of about 20 mm. A portion, of the rachis of each artificial feather, that measures about 15 mm from the tail end of the rachis is inserted into the base portion. An inner diameter at leading end portions of the 16 artificial feathers is about 68 mm. In this case, the angle, of spreading toward the end, of a feather portion is about 24 degrees.

[0096] The badminton shuttlecock 20 may further include joining-and-fixing members 23 (for example, yarns, ribs, or the like) for joining and fixing the plurality of artificial feathers to each other. Strings are wound at positions, on each rachis, that are respectively 12 mm and 24 mm away from the upper surface of the base portion. Each vane portion is formed from a position, on the corresponding rachis, that is 24 mm away from the upper surface of the base portion to the leading end of the rachis.

[0097] The mass of the shuttlecock is set to 4.74 g to 5.50 g.

EXAMPLES

[0098] Hereinafter, the present invention will be described in detail by means of examples, but the present invention is not limited to the following examples, and any of modifications and implementation modes made within the scope of the gist of the present invention is included in the scope of the present invention.

[Evaluation Methods]

(1) Expansion Ratio

[0099] An expansion ratio was calculated from the thickness of a foamed resin plate/the thickness of a non-foamed resin plate, the resin plates having been made by using the same mold.

(2) Density (Apparent Density)

[0100] A 2-cm-square test piece was stamped from a resin plate having a thickness of 2 mm, and the density of the test piece was measured according to the standard of "JIS K 7112 (1999)" .

(3) Flexural Modulus of Elasticity

[0101] A flexural modulus of elasticity was measured according to JIS K 7171 (2016). Specifically, a foamed resin plate was made under conditions (the same conditions as those for making the rachis) indicated in Table 1 by using a mold with an original thickness of 2 mm, and the flexural modulus of elasticity of the foamed resin plate was measured.

(4) Flexural Rigidity

[0102] A flexural rigidity was measured in a cantilever compression test. Specifically, a test piece (thickness: 2 mm) was stamped from a resin plate so as to have a width of 2 cm and a length of 10 cm. The test piece was, at a position thereon that was 12 mm away from the leading end of the test piece, fixed with a chuck portion by using AUTOGRAPH (AG-100kNX Plus equipped with a 100-N load cell) manufactured by Shimadzu Corporation. The test piece was, at a position thereon that was 55 mm away from the chuck portion, compressed at 1 mm/second by using an indenter having a radius of 5 mm, and a test force was measured upon displacement by 10 mm. The test force was regarded as the flexural rigidity of the test piece. Table 1 indicates the flexural rigidity of each test piece as a relative value to the flexural rigidity, of a solid-structure test piece No. 7, which is regarded as 100.

[Making Test Pieces]

[0103] By using an electric injection molding machine (JL10AD-180H manufactured by The Japan Steel Works, LTD.) and a supercritical fluid manufacturing unit (SCF system T-100J manufactured by TREXEL INC.), each of ABS/PC resins (MULTILON T3615-Q manufactured by TEIJIN LIMITED.) was heated and melted in a cylinder at a setting temperature of 240 to 250°C, nitrogen in a supercritical state was introduced to the ABS/PC resin, and the ABS/PC resin was melt-kneaded. Then, the melt-kneaded product was injected into a mold at a setting temperature of 60°C, and the ABS/PC resin was foamed by the core-back method, whereby a foam-molded article was made. The foam-molded article had a size of 15 cm × 15 cm × thickness (mm). A test piece having a size of 10 cm long × 2 cm wide × thickness (mm) was made out of the foam-molded article. Table 1 indicates conditions of foam molding and the physical properties of the obtained test pieces.

[Table 1]

Test pieces (foam-molded articles)		No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	No. 11
Conditions of foam molding	Introduction amount of nitrogen per 100 parts by mass of resin composition (parts by mass)	0.3	0.3	0.3	0.5	0.5	0.5	-	0.3	0.5	0.3	0.3
	Injection speed of melt-kneaded product (mm/s)	200	200	200	200	20	50	50	50	50	200	200
	Standby time taken until core-back is started (sec)	1	0.1	1	1	0.1	1	-	0.1	0.1	1	1
	Core-back time (sec)	1	0.5	0.5	1	0.5	1	-	0.5	0.5	1	1
Physical properties of foam-molded articles	Thickness (mm)	3.07	4.00	4.01	4.07	4.02	4.09	2.10	4.00	3.99	5.00	6.00
	Expansion ratio (time)	1.5	1.9	1.9	1.9	1.9	1.9	-	1.9	1.9	2.4	2.9
	Density (g/cm^3)	0.84	0.64	0.64	0.63	0.64	0.61	1.13	0.62	0.62	0.51	0.43
	Flexural modulus of elasticity (GPa)	1.80	1.10	1.20	1.10	1.00	1.20	2.10	0.90	1.00	0.60	0.08
	Flexural modulus of elasticity × thickness	5.52	4.40	4.81	4.48	4.02	4.90	4.42	3.60	3.99	3.00	0.50
	Flexural rigidity (relative value to flexural rigidity of test piece No. 7 regarded as 100)	243	339	388	328	281	372	100	127	184	292	252

[0104] Test pieces No. 1 to 6 and 8 to 11 were formed by foaming respective rachis resin compositions, and have solid structures on the surface layer portions and foamed structures inside the test pieces. As seen from the results in Table 1, these test pieces No. 1 to 6 and 8 to 11 have, while having lower densities, higher rigidities than the solid-structure test piece No. 7 having an equivalent mass. If such foam-molded articles are used as rachises, a badminton shuttlecock that is light and that has a high durability can be expected to be obtained.

Claims

1. A shuttlecock artificial feather (1) comprising:

   a vane portion (3); and
   a rachis portion (5) fastened to the vane portion (3), wherein
   the rachis portion (5) includes

      a core portion region (11) having pores, and
      an outer layer region (13) coating the core portion region (11) and having a solid structure.

2. The shuttlecock artificial feather (1) according to claim 1, wherein the core portion region (11) and the outer layer region (13) coating the core portion region (11) are included over an entirety in an axial direction (B) of the rachis portion (5).

3. The shuttlecock artificial feather (1) according to claim 1 or 2, wherein

   the rachis portion (5) further includes

      a fastened-to-vane portion (5a) fastened to the vane portion (3),
      a root portion (5c) to be inserted into a shuttlecock (20), and
      an intermediate portion (5b) located between the fastened-to-vane portion (5a) and the root portion (5c), and

   a density D1 of the fastened-to-vane portion (5a) is lower than a density D2 of the root portion (5c).

4. The shuttlecock artificial feather (1) according to any one of claims 1 to 3, wherein a height H1 in an up-down direction (A) of a leading end (7) of the rachis portion (5) is lower than a height H2 in the up-down direction (A) of a tail end (9) of the rachis portion (5).

5. The shuttlecock artificial feather (1) according to any one of claims 1 to 4, wherein a flexural modulus of elasticity of the outer layer region (13) is 1.5 GPa to 12 GPa.

6. The shuttlecock artificial feather (1) according to any one of claims 1 to 5, wherein a thickness of the outer layer region (13) is 0.05 mm to 0.60 mm.

7. The shuttlecock artificial feather (1) according to any one of claims 1 to 6, wherein a density of an entirety of the rachis portion (5) is 0.52 g/cm^3 to 1.00 g/cm^3.

8. The shuttlecock artificial feather (1) according to any one of claims 1 to 7, wherein a product of a flexural modulus of elasticity (GPa) and a thickness (mm) of a foam-molded article of a rachis resin composition that forms the rachis portion (5) is not smaller than 4.0.

9. The shuttlecock artificial feather (1) according to claim 8, wherein a density of the foam-molded article is 0.52 g/cm^3 to 1.00 g/cm^3.

10. The shuttlecock artificial feather (1) according to any one of claims 1 to 9, wherein the pores are one of independent pores and continuous pores.

11. The shuttlecock artificial feather (1) according to any one of claims 1 to 10, wherein a diameter of each pore is not larger than 1000 μm, more preferably not larger than 500 μm, and further preferably not larger than 100 μm.

12. A badminton shuttlecock (20) comprising:

a hemispherical base portion (21); and
the shuttlecock artificial feather (1) according to any one of claims 1 to 11 provided to the base portion (21).

13. A method for manufacturing a shuttlecock artificial feather (1), the method comprising the steps of:

melt-kneading a rachis resin composition;
introducing a foaming agent as a supercritical fluid to the melted rachis resin composition, to make a melt-kneaded product;
injecting the melt-kneaded product into a mold;
reducing at least one of a pressure and a temperature of the foaming agent to be lower than a critical point of the foaming agent so that the resin composition is foamed, to make a rachis portion (5); and
fastening the rachis portion (5) and a vane portion (3) to each other.

14. The method for manufacturing a shuttlecock artificial feather (1) according to claim 13, wherein at least one of the pressure and the temperature is reduced to be lower than the critical point of the foaming agent by a core-back method.

15. The method for manufacturing a shuttlecock artificial feather (1) according to claim 14, wherein the rachis portion (5) is made under a same condition as a core-back molding condition in which, when the foam-molded article is molded from the rachis resin composition by the method according to claim 13, a product of a flexural modulus of elasticity (GPa) and a thickness (mm) of the foam-molded article is not smaller than 4.0 and a density of the foam-molded article is not higher than 1.00 g/cm^3.

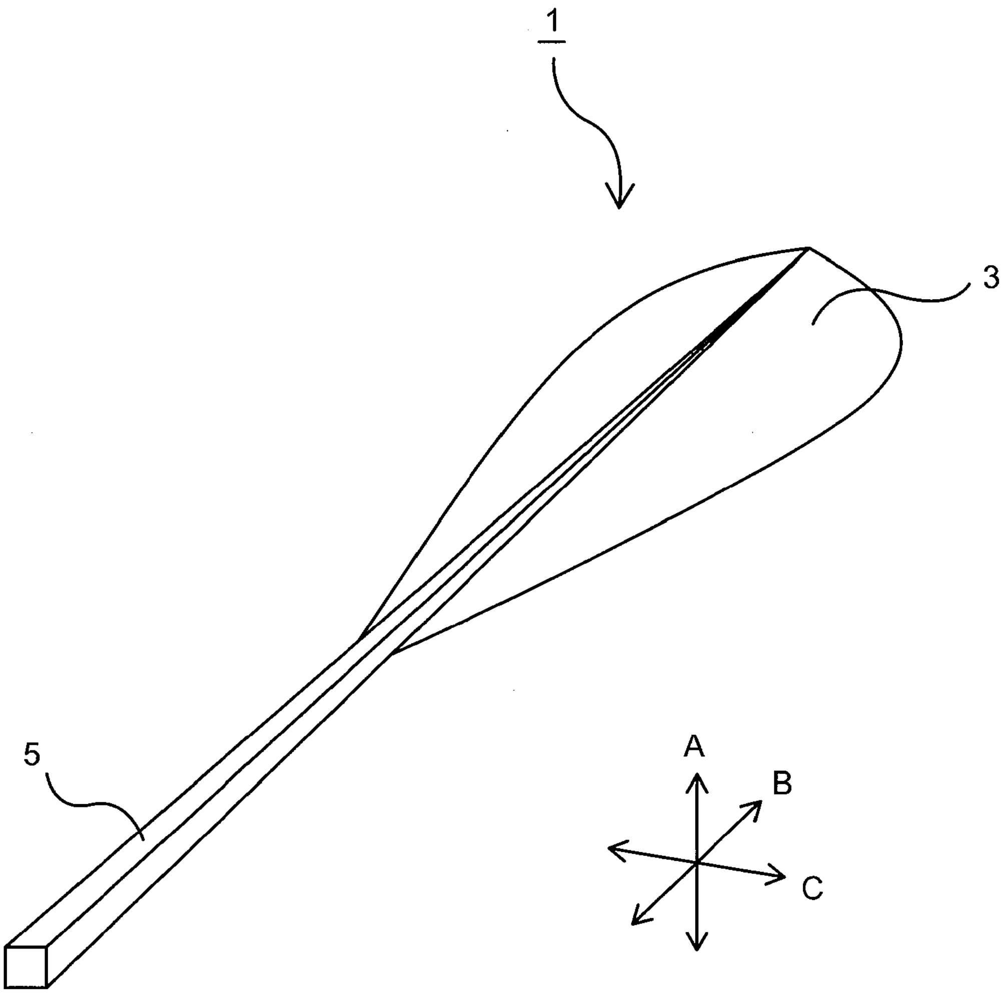

Fig. 1

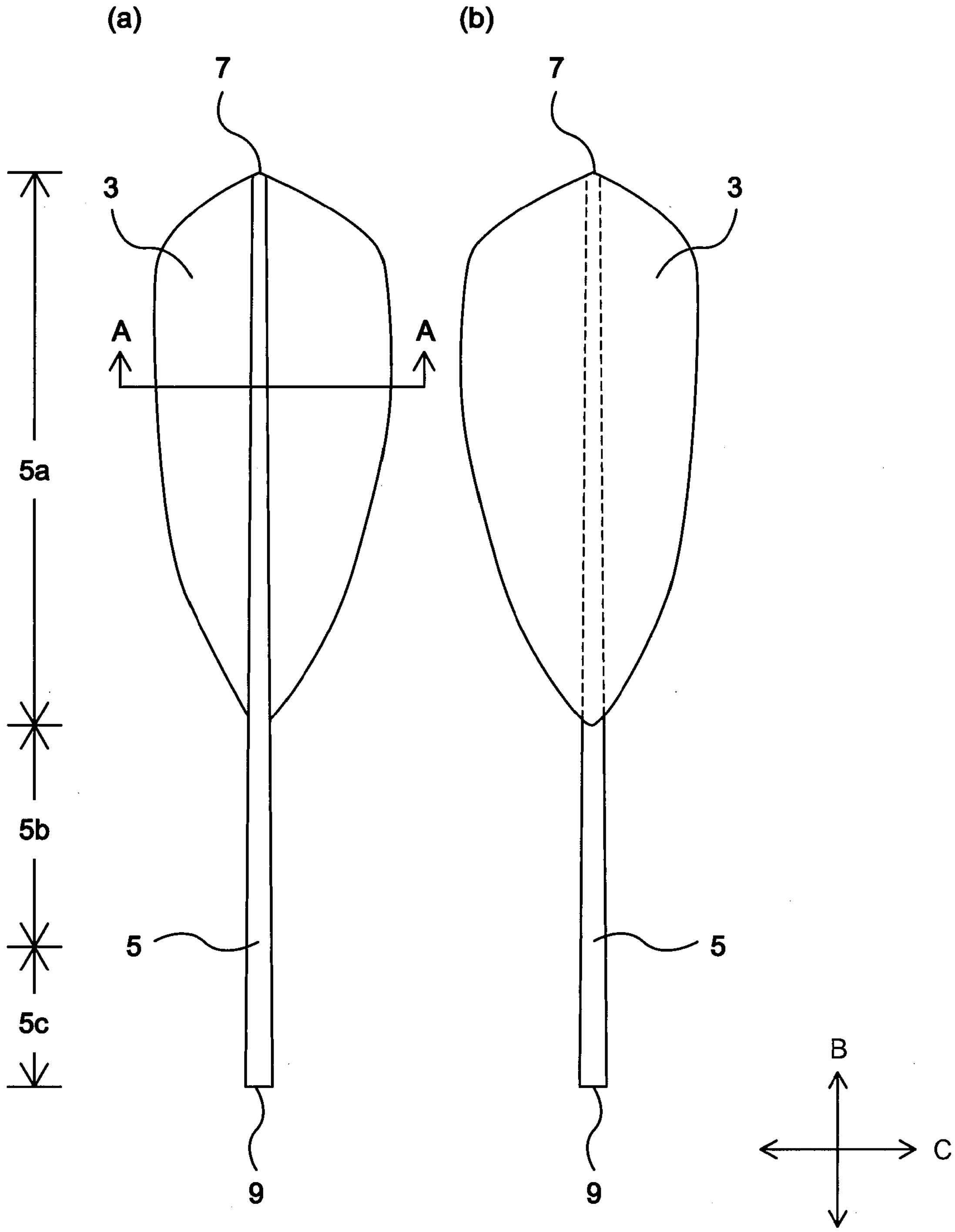

Fig. 2

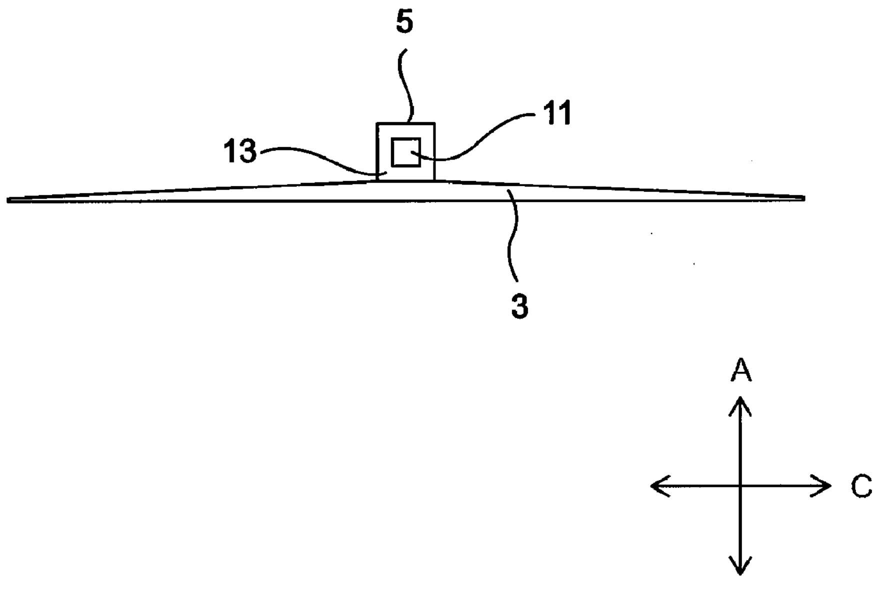

Fig. 3

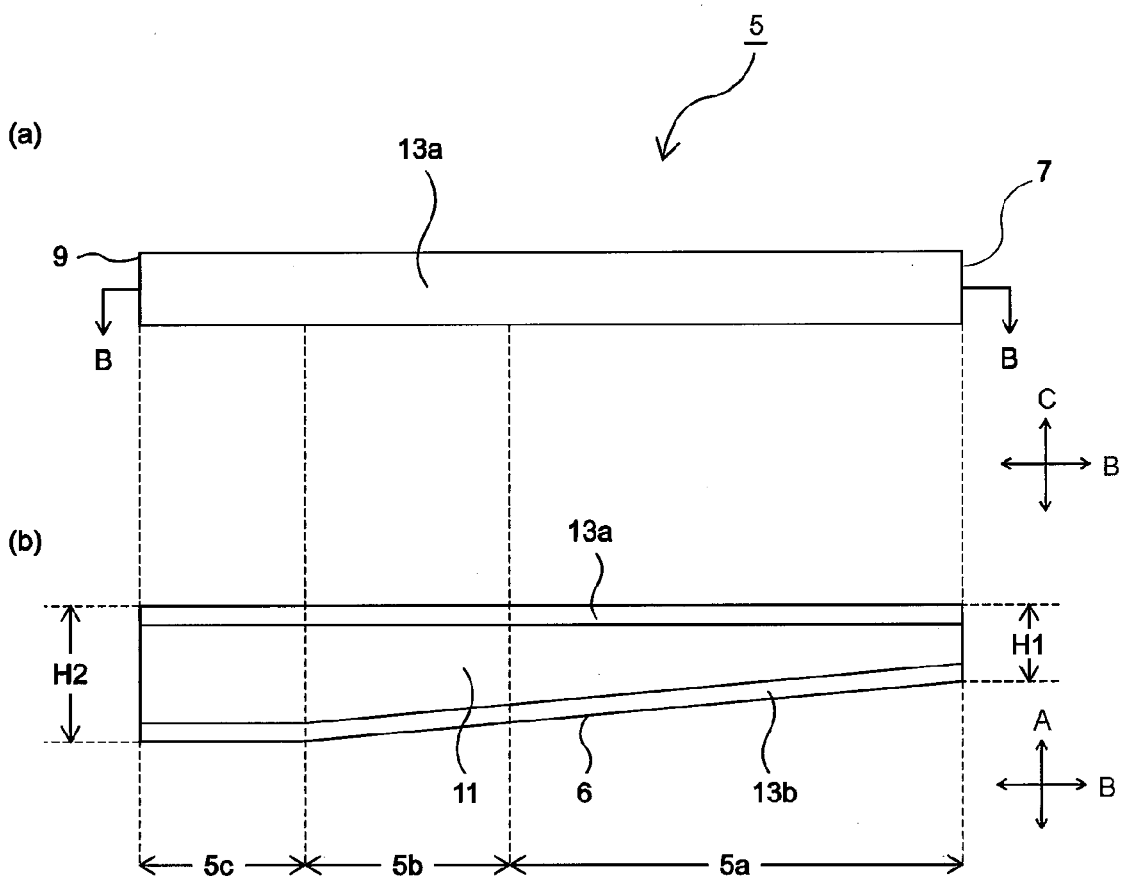

Fig. 4

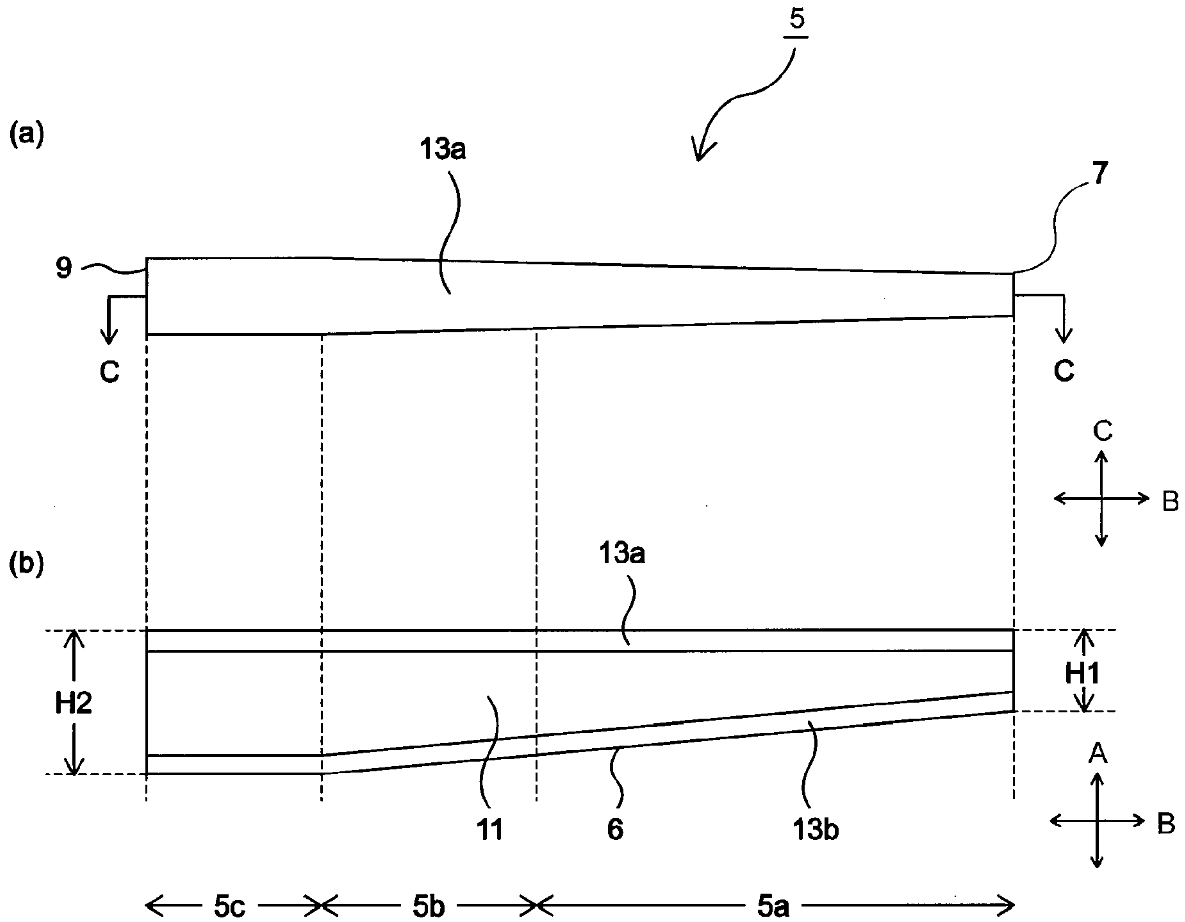

Fig. 5

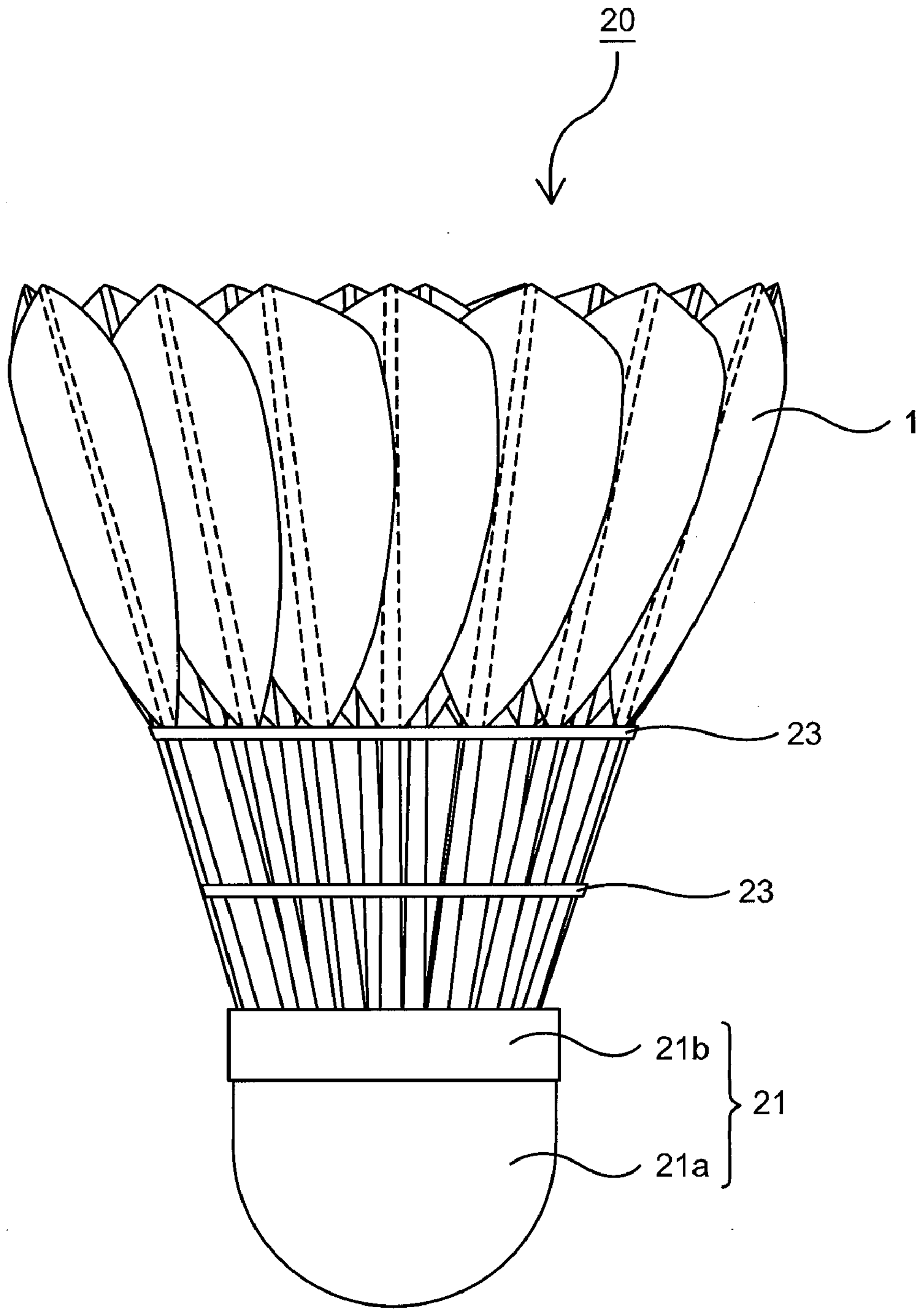

Fig. 6

REFERENCES CITED IN THE DESCRIPTION

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