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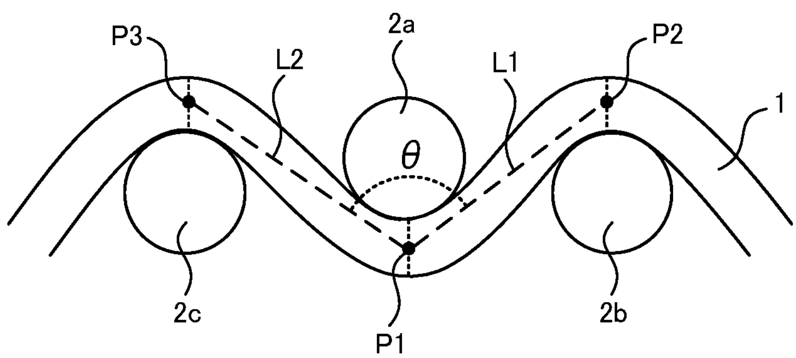
(54) **MESH TEXTILE**

(57) [Problem] Provided is a mesh woven fabric that allows for isotropic deformation when an external load acts thereon.

[Solution] In a mesh woven fabric including a warp thread and a weft thread, a bending angle of the warp thread and a bending angle of the weft thread at an intersection where the warp thread and the weft thread intersect each other are different from each other. A rate of an absolute value of a bending angle difference between the warp thread and the weft thread to an average of the bending angle of the warp thread and the bending angle of the weft thread is 20% or less. At least one of the warp thread and the weft thread can be composed of a synthetic fiber.

FIG.1



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Description

Technical Field

[0001] The present invention relates to a mesh woven fabric that allows for isotropic deformation.

Background Art

[0002] In salt electrolyzers, water electrolyzers, and the like, an ion exchange membrane for exchange of various ions is used. The ion exchange membrane is often required to have high durability, and is required to have high mechanical strength against various solvents and high-temperature environments. Therefore, a method of reinforcing the ion exchange membrane by forming a composite of a resin having ion permeability and a support formed of a mesh or a nonwoven fabric has been adopted.

[0003] Patent Literature 1 describes that use of a reinforcing material (woven fabric or nonwoven fabric) formed of reinforcing fibers such as polytetrafluoroethylene (PTFE) improves the strength of an ion exchange membrane.

Citation List

Patent Literature

[0004] Patent Literature 1: JP 2000-297164 A

Summary of Invention

Technical Problem

[0005] It is known that an ion exchange membrane is deformed by receiving an external load such as heat or an external force. Here, when the reinforcing material (woven fabric) of the ion exchange membrane is anisotropically deformed by an external load, stress acting on the ion exchange membrane becomes non-uniform and concentrates on a part of the ion exchange membrane. As a result, the ion exchange membrane may be damaged.

[0006] An object of the present invention is to provide a mesh woven fabric capable of allowing for isotropic deformation when receiving an external load.

Solution to Problem

[0007] The gist of the present invention is as follows.

[1] A mesh woven fabric including a warp thread and a weft thread, wherein

a bending angle of the warp thread and a bending angle of the weft thread at an intersection where the warp thread and the weft thread intersect each other are different from each other, and
a rate of an absolute value of a bending angle difference between the warp thread and the weft thread to an average of the bending angle of the warp thread and the bending angle of the weft thread is 20% or less.

[2] The mesh woven fabric according to [1], which satisfies at least one of conditions described below:

a rate of an absolute value of a tensile strength difference between a warp direction and a weft direction to an average of a tensile strength in the warp direction and a tensile strength in the weft direction is 20% or less;
a rate of an absolute value of a tensile elongation difference between the warp direction and the weft direction to an average of a tensile elongation in the warp direction and a tensile elongation in the weft direction is 68% or less; and
in curves showing a relation between a tensile load and a tensile elongation percentage, with respect to slopes in elastic deformation regions of the curves, a rate of an absolute value of a slope difference between the warp direction and the weft direction to an average of a slope for the warp direction and a slope for the weft direction is 62% or less.

[3] The mesh woven fabric according to [1] or [2], wherein a rate of an absolute value of a thermal deformation amount difference between a warp direction and a weft direction to an average of a thermal deformation amount in the warp

direction and a thermal deformation amount in the weft direction is 180% or less.

[4] The mesh woven fabric according to [1], wherein at least one of the warp thread and the weft thread is a synthetic fiber.

[5] The mesh woven fabric according to [4], wherein the synthetic fiber is a PE fiber, a PTFE fiber, a PPS fiber, an LCP fiber, or a PEEK fiber.

Advantageous Effects of Invention

[0008] According to the present invention, when the bending angle of the warp yarn and the bending angle of the weft thread are different from each other, and the rate of the absolute value of the bending angle difference between the warp thread and the weft thread to the average of the bending angle of the warp thread and the bending angle of the weft thread is 20% or less, the mesh woven fabric easily allows for isotropic deformation.

Brief Description of Drawing

[0009] **Fig.** 1 is a drawing illustrating a bending angle of a warp thread.

Description of Embodiment

[0010] In the following, a mesh woven fabric that is an embodiment of the present invention is described. The mesh woven fabric is a woven fabric composed of a plurality of warp threads and a plurality of weft threads. In the present embodiment, as will be described later, the bending angle of the warp thread and the bending angle of the weft thread are focused on so that the mesh woven fabric can allow for isotropic deformation.

[0011] The application of the mesh woven fabric is not particularly limited, and for example, the mesh woven fabric can be used as a reinforcing material of an ion exchange membrane. According to the present embodiment, when an external load such as heat or an external force acts on the mesh woven fabric, the mesh woven fabric allows for isotropic deformation, so that stress concentration on a part of the mesh woven fabric is reduced. As for an article (product) intended to reduce stress concentration due to an external load, the mesh woven fabric of the present embodiment can be used.

[0012] A loom for producing the mesh woven fabric is not particularly limited, and for example, a shuttle loom, a gripper loom, a rapier loom, a water-jet loom, or an airjet loom can be used. The mesh woven fabric produced by the loom can be subjected to a heat application treatment (heat setting).

[0013] The bending angle of the warp thread is an angle at which the warp thread bends at an intersection where the warp thread and the weft thread intersect each other. The bending angle of the warp thread can be measured by cutting the mesh woven fabric at an intersection between the warp thread and the weft thread along the longitudinal direction of the weft thread (hereinafter, the direction is referred to as a "weft direction"), and observing the cut surface with a microscope (for example, an optical microscope). Fig. 1 shows a schematic view of the cut surface that is made when measuring the bending angle of the warp thread. In Fig. 1, one warp thread 1 extends in the horizontal direction of Fig. 1, and three weft threads 2a, 2b, and 2c are arranged in the horizontal direction of Fig. 1 at predetermined intervals. The weft threads 2a, 2b, and 2c extend in a direction orthogonal to the plane of Fig. 1.

[0014] An angle θ illustrated in Fig. 1 is the bending angle of the warp thread 1 at an intersection between the warp thread 1 and the weft thread 2a. The bending angle θ is an angle (acute angle) formed by a straight line L1 connecting two reference points P1 and P2 and a straight line L2 connecting two reference points P1 and P3. Identification of the reference points P1 to P3 by the above-described microscopic observation of the cut surface enables measurement of the bending angle θ on the basis of the straight lines L1 and L2.

[0015] The reference point P1 is a point at which the radius of curvature of the warp thread 1 is the smallest at the intersection between the warp thread 1 and the weft thread 2a, and is located at the center in the radial direction of the warp thread 1. The reference point P2 is a point at which the radius of curvature of the warp thread 1 is the smallest at the intersection between the warp thread 1 and the weft thread 2b (a weft thread adjacent to the weft thread 2a), and is located at the center in the radial direction of the warp thread 1. The reference point P3 is a point at which the radius of curvature of the warp thread 1 is the smallest at the intersection between the warp thread 1 and the weft thread 2c (a weft thread adjacent to the weft thread 2a), and is located at the center of the warp thread 1.

[0016] The bending angle of the weft thread is an angle at which the weft thread bends at an intersection where the warp thread and the weft thread intersect each other. The bending angle of the weft thread can be measured by cutting the mesh woven fabric at an intersection between the warp thread and the weft thread along the longitudinal direction of the warp thread (hereinafter, the direction is referred to as a "warp direction"), and observing the cut surface with a microscope (for example, an optical microscope). Similarly to the above-described method for measuring the bending angle of the warp thread, identification of the three reference points P1 to P3 on the cut surface enables measurement of the bending angle of the weft thread on the basis of the straight lines L1 and L2. More specifically, in Fig. 1, the bending angle θ of the weft thread can be measured by replacing the warp thread 1 with a weft thread and replacing the weft threads 2a to 2c with warp threads.

[0017] A bending angle difference $\Delta\theta$ can be determined by measuring a bending angle $\theta 1$ of the warp thread and a bending angle $\theta 2$ of the weft thread at the intersection between the warp thread and the weft thread as described above. As shown in the following formula (1), the bending angle difference $\Delta\theta$ is an index related to a difference between the bending angles $\theta 1$ and $\theta 2$.

[Mathematical formula 1]

$$\Delta\theta = \frac{|\theta 1 - \theta 2|}{\theta \mathrm{ave}} \times 100 \cdots (1)$$

[0018] In the above formula (1), $\Delta\theta$ is the above-described bending angle difference [%], $\theta 1$ is the bending angle [°] of the warp thread, $\theta 2$ is the bending angle [°] of the weft thread, and θave is an average of the bending angles $\theta 1$ and $\theta 2$ ($\theta \mathrm{ave} = (\theta 1 + \theta 2)/2$). According to the above formula (1), the bending angle difference $\Delta\theta$ indicates the rate of (the absolute value of) the difference between the bending angles $\theta 1$ and $\theta 2$ to the average θave.

[0019] For $\theta 1$ in the above formula (1), any of the following may be used: the bending angle [°] of the warp thread at one intersection of the mesh woven fabric, the average of the bending angles [°] of the warp threads at two or more intersections, and the average of the bending angles [°] of the warp threads at all the intersections. Similarly, for $\theta 2$ in the above formula (1), any of the following may be used: the bending angle [°] of the weft thread at one intersection of the mesh woven fabric, the average of the bending angles [°] of the weft threads at two or more intersections, and the average of the bending angles [°] of the weft threads at all the intersections.

[0020] In the present embodiment, the bending angles $\theta 1$ and $\theta 2$ are made different from each other, and on this premise, the bending angle difference $\Delta\theta$ is set to be 20[%] or less. That is, in the present embodiment, the bending angle difference $\Delta\theta$ is more than 0[%] and 20[%] or less. Here, the magnitude relationship between the bending angles $\theta 1$ and $\theta 2$ does not matter, and the bending angle $\theta 1$ may be larger than the bending angle $\theta 2$, or the bending angle $\theta 1$ may be smaller than the bending angle $\theta 2$. Since the bending angle difference $\Delta\theta$ is set to 20[%] or less, as can be understood from the section of examples described later, the mesh woven fabric can be isotropically deformed when an external load acts thereon. The isotropic deformation means uniform deformation in all directions in a two-dimensional plane including the warp direction and the weft direction.

[0021] When the mesh woven fabric is isotropically deformed, stress concentration on a part of the mesh woven fabric due to an external load can be reduced. For example, when a mesh woven fabric is used as a reinforcing material of an ion exchange membrane and an external load acts on the ion exchange membrane, stress acting on the ion exchange membrane can be distributed to reduce stress concentration on a part of the ion exchange membrane. As a result, damage to the ion exchange membrane due to stress concentration can be reduced.

[0022] In order to set the bending angle difference $\Delta\theta$ to 20[%] or less, the bending angles $\theta 1$ and $\theta 2$ should be controlled so that this condition may be satisfied. Here, in the production of the mesh woven fabric, the bending angles $\theta 1$ and $\theta 2$ can be controlled by adjusting the tension of the warp thread and the cross timing (in a loom, an angle at which the heddle being driven is in a closed state), and the bending angle difference $\Delta\theta$ can be set to 20[%] or less regardless of the position in the mesh woven fabric.

[0023] In the present embodiment, the bending angle difference $\Delta\theta$ is required to be 20[%] or less. However, from the viewpoint of more isotropically deforming the mesh woven fabric, the bending angle difference $\Delta\theta$ is preferably 17[%] or less, and more preferably 10[%] or less. The lower limit of the bending angle difference $\Delta\theta$ is required to be 0[%] or more, and is preferably 1[%] or more.

[0024] In the present embodiment, as long as the bending angle difference $\Delta\theta$ is 20[%] or less, the ranges of the bending angle $\theta 1$ of the warp thread, the bending angle $\theta 2$ of the weft thread, and the absolute value of the difference therebetween (hereinafter, also referred to as "absolute value $|\theta 1 - \theta 2|$") are not particularly limited. Meanwhile, from the viewpoint of more isotropically deforming the mesh woven fabric, the bending angle $\theta 1$ of the warp thread is preferably 120[°] or more and 190[°] or less, and more preferably 130[°] or more and 180[°] or less. From the viewpoint of more isotropically deforming the mesh woven fabric, the bending angle $\theta 2$ of the weft thread is also preferably 120[°] or more and 190[°] or less, and more preferably 130[°] or more and 180[°] or less. From the viewpoint of more isotropically deforming the mesh woven fabric, the absolute value $|\theta 1 - \theta 2|$ is preferably more than 0[°] and 30[°] or less, and more preferably more than 0[°] and 27[°] or less.

[0025] The diameters of the warp thread and the weft thread may be substantially equal to each other within the production error, or may be different from each other. When the diameters of the warp thread and the weft thread are made substantially equal to each other, the mesh woven fabric is easily isotropically deformed as compared with the case where the diameters of the warp thread and the weft thread are made different.

[0026] The diameters of the warp thread and the weft thread are not particularly limited, but are preferably each 200 μm or less. When the diameters of the warp thread and the weft thread are each 200 μm or less, the rate of the volume of the threads to the volume of the entire mesh woven fabric (including the opening portions) can be reduced. In other words, the rate of the volume of the opening portions to the volume of the entire mesh woven fabric (including the opening portions) can be increased.

[0027] Accordingly, when the mesh woven fabric is used as a reinforcing material of an ion exchange membrane, proton conduction through the opening portions is easily maintained. In consideration of this point, the diameters of the warp thread and the weft thread are preferably as small as possible, and are more preferably each 100 μm or less, still more preferably each 80 μm or less, and particularly preferably each 60 μm or less. Meanwhile, if the diameters of the warp thread and the weft thread are too small, the mechanical strength of the mesh woven fabric (threads) tends to be reduced. Therefore, the diameters of the warp thread and the weft thread are preferably each 10 μm or more.

[0028] The mesh count of the mesh woven fabric is not particularly limited. The mesh count can be appropriately determined according to the application of the mesh woven fabric.

[0029] The mesh opening of the mesh woven fabric can be set to 30 μm or more. In the mesh woven fabric, the mesh opening is the distance between two warp threads adjacent in the weft direction or the distance between two weft threads adjacent in the warp direction, and is the length of one side of an opening portion formed in the mesh woven fabric. The mesh opening can be determined from the following formula (2).

[Mathematical formula 2]

$$\mathrm{OP} = \left(\frac{25400}{\mathrm{M}}\right) - \mathrm{D} \cdots (2)$$

[0030] In the above formula (2), OP is the mesh opening [μm], M is the mesh count [mesh/inch], and D is the diameter [μm] of the warp thread or the weft thread. The mesh count M is the number of threads per 1 inch (2.54 cm) width of the mesh woven fabric. As shown in the above formula (2), the mesh opening OP can be determined from the mesh count M and the diameter D of the thread.

[0031] When the mesh opening is set to 30 μm or more, the opening portions of the mesh woven fabric can be enlarged. For this reason, when the mesh woven fabric is used as a reinforcing material of an ion exchange membrane, proton conduction through the opening portions is easily maintained. In consideration of this point, the mesh opening is preferably as large as possible, and is more preferably 40 μm or more, and still more preferably 50 μm or more. Meanwhile, if the mesh opening is made too large, the mesh woven fabric becomes difficult to function as a reinforcing material of an ion exchange membrane, and thus the mesh opening is preferably 200 μm or less.

[0032] The opening area of the mesh woven fabric is preferably 30% or more. The opening area is an index representing the area rate of the opening portions of the mesh woven fabric, and is determined from the following formula (3).

[Mathematical formula 3]

$$\mathrm{OPA} = \left[\frac{\mathrm{OP}^2}{(\mathrm{OP}+\mathrm{D})^2}\right] \times 100 \cdots (3)$$

[0033] In the above formula (3), OPA is the opening area [%], OP is the mesh opening [um], and D is the diameter [μm] of the warp thread or the weft thread.

[0034] When the opening area is set to 30% or more, the area rate of the opening portions of the mesh woven fabric can be increased. For this reason, when the mesh woven fabric is used as a reinforcing material of an ion exchange membrane, proton conduction through the opening portions is easily maintained. In consideration of this point, the opening area is preferably as large as possible, and is more preferably 40% or more. Meanwhile, if the opening area is made too large, the mesh woven fabric becomes difficult to function as a reinforcing material of an ion exchange membrane, and thus the opening area is preferably 90% or less.

[0035] The weave structure of the mesh woven fabric is not particularly limited, and for example, plain weave or twill weave can be adopted. When it is required to reduce the thickness (gauze thickness) of the mesh woven fabric, it is preferable to adopt plain weave as the weave structure.

[0036] The warp thread and the weft thread are preferably monofilaments. When monofilaments are used, the width of the threads (the substantial diameter of the threads) can be reduced as compared with the case of using multifilaments, so that the opening portions of the mesh woven fabric can be easily enlarged as described above.

[0037] Since multifilaments are often formed by twisting a plurality of monofilaments, the multifilaments are likely to have, depending on the longitudinal position on the thread, variation in the outer shape. Meanwhile, the monofilaments are less likely to have the above-described variation in the outer shape than the multifilaments do. Therefore, when monofilaments are used as the warp thread and the weft thread, variation in mesh opening can be easily reduced in the entire mesh woven fabric. When the variation in mesh opening is reduced, the mesh woven fabric is more easily isotropically deformed.

[0038] The materials of the warp thread and the weft thread are not particularly limited, but are preferably flexible synthetic fibers. As for the material of the synthetic fibers, for example, polyethylene terephthalate, polypropylene, 6-nylon, 66-nylon, polyethylene (PE), an ethylene-vinyl acetate copolymer, polycarbonate, polyphenylene sulfide (PPS), polyethylene naphthalate, polyetheretherketone (PEEK), modified polyphenylene ether (PPE), polyaryletherketone (PAEK), polystyrene (PS) including crystalline polystyrene such as syndiotactic polystyrene (SPS) and isotactic polystyrene, and polyimide (PI) can be used. As for the material of the synthetic fibers, thermoplastic resins such as aramid, polyarylate, ultra-high molecular weight polyethylene, polyparaphenylene benzobisoxazole (PBO), polyparaphenylene benzobisthiazole (PBT), polyparaphenylene benzobisimidazole (PBI), polyacetal resin, polyarylate resin, polysulfone resin, polyvinylidene fluoride resin, ethylene tetrafluoroethylene (ETFE), and polytetrafluoroethylene (PTFE), biodegradable resins such as polylactic acid resin, polyhydroxybutyrate resin, modified starch resin, polycaprolactone resin, polybutylene succinate resin, polybutylene adipate terephthalate resin, polybutylene succinate terephthalate resin, and polyethylene succinate resin, thermosetting resins such as phenol resin, urea resin, melamine resin, unsaturated polyester resin, diallyl phthalate resin, epoxy resin, epoxy acrylate resin, silicon resin, acrylic urethane resin, and urethane resin, and elastomers such as silicone resin, polystyrene elastomer, polyethylene elastomer, polypropylene elastomer, and polyurethane elastomer can also be used. Furthermore, fluorine-based fibers, carbon fibers, liquid crystalline polymer (LCP) fibers, and fibers produced from natural resins such as lacquer, and the like can be used as the warp thread and the weft thread.

[0039] Each of the warp thread and the weft thread can also be formed using two or more of the above-described materials. Specifically, a thread having a core-sheath structure can be used, and the material of the core portion and the material of the sheath portion can be made different from each other. In addition, the warp thread and the weft thread may be made from different materials from each other. When heat resistance or solvent resistance is imparted to the threads of the mesh woven fabric, it is preferable to use synthetic fiber threads. As the synthetic fiber, a PE fiber, a PTFE fiber, a PPS fiber, an LCP fiber, a PAEK fiber, an SPS fiber, or a PEEK fiber can be used, and a PE fiber, a PTFE fiber, a PPS fiber, an LCP fiber, or a PEEK fiber is more preferable.

[0040] As a result of a tensile test of the mesh woven fabric, a curve showing a relation between the tensile load [N] and the tensile elongation percentage [%] (hereinafter, the curve is referred to as a "tensile load-tensile elongation percentage curve") is obtained. In the tensile test of the mesh woven fabric, the tensile elongation percentage increases as the tensile load is increased, and the threads of the mesh woven fabric are broken when the tensile load reaches the limit value (tensile strength). The tensile elongation percentage when the threads of the mesh woven fabric are broken is the tensile elongation. The tensile test in the warp direction provides a tensile load-tensile elongation percentage curve for the warp direction, and the tensile test in the weft direction provides a tensile load-tensile elongation percentage curve for the weft direction. The tensile test is performed in accordance with JIS L1096 (Method A (JIS method)).

[0041] Focusing on the slopes [N/%] of the tensile load-tensile elongation percentage curves, as shown in the following formula (4), a "slope difference", which is an index related to a difference between the slope for the warp thread and the slope for the weft thread, can be obtained. The slope of each of the tensile load-tensile elongation percentage curves is the slope in an elastic deformation region of the tensile load-tensile elongation percentage curve.

[Mathematical formula 4]

$$\Delta SL = \frac{|SL1 - SL2|}{SLave} \times 100 \cdots (4)$$

[0042] In the above formula (4), ΔSL is the above-described slope difference [%], SL1 is the slope [N/%] for the warp thread, SL2 is the slope [N/%] for the weft thread, and SLave is an average of the slopes SL1 and SL2 (SLave = (SL1 + SL2)/2). According to the above formula (4), the slope difference ΔSL indicates the rate of (the absolute value of) the difference between the slopes SL1 and SL2 to the average SLave.

[0043] The slope difference ΔSL is preferably 62% or less (that is, 0% or more and 62% or less). If the slope difference ΔSL is larger than 62%, the anisotropy of deformation of the mesh woven fabric tends to be strong. Therefore, in order to isotropically deform the mesh woven fabric, it is preferable to set the slope difference ΔSL to 62% or less. From the viewpoint of more isotropically deforming the mesh woven fabric, the slope difference ΔSL is preferably 55% or less (that is, 0% or more and 55% or less).

[0044] As a result of a tensile test of the mesh woven fabric, tensile strength in the warp direction and tensile strength in the weft direction are determined. Then, as shown in the following formula (5), a "tensile strength difference", which is an index related to a difference between the tensile strength in the warp direction and the tensile strength in the weft direction, can be determined.

[Mathematical formula 5]

$$\Delta S = \frac{|S1 - S2|}{Save} \times 100 \cdots (5)$$

[0045] In the above formula (5), ΔS is the above-described tensile strength difference [%], S1 is the tensile strength [N] of the warp thread, S2 is the tensile strength [N] of the weft thread, and Save is an average of the tensile strengths S1 and S2 (Save = (S1 + S2)/2). According to the above formula (5), the tensile strength difference ΔS indicates the rate of (the absolute value of) the difference between the tensile strengths S1 and S2 to the average Save.

[0046] The tensile strength difference ΔS is preferably 20% or less (that is, 0% or more and 20% or less). If the tensile strength difference ΔS is larger than 20%, the anisotropy of deformation of the mesh woven fabric tends to be strong. Therefore, in order to isotropically deform the mesh woven fabric, it is preferable to set the tensile strength difference ΔS to 20% or less. From the viewpoint of more isotropically deforming the mesh woven fabric, the tensile strength ΔS is preferably 18% or less (that is, 0% or more and 18% or less).

[0047] As a result of a tensile test of the mesh woven fabric, tensile elongation in the warp direction and tensile elongation in the weft direction are determined. Then, as shown in the following formula (6), a "tensile elongation difference", which is an index related to a difference between the tensile elongation in the warp direction and the tensile elongation in the weft direction, can be determined.

[Mathematical formula 6]

$$\Delta L = \frac{|L1 - L2|}{Lave} \times 100 \cdots (6)$$

[0048] In the above formula (6), ΔL is the above-described tensile elongation difference [%], L1 is the tensile elongation [%] of the warp thread, L2 is the tensile elongation [%] of the weft thread, and Lave is an average of the tensile elongations L1 and L2 (Lave = (L1 + L2)/2). According to the above formula (6), the tensile elongation difference ΔL indicates the rate of (the absolute value of) the difference between the tensile elongations L1 and L2 to the average Lave.

[0049] The tensile elongation difference ΔL is preferably 68% or less (that is, 0% or more and 68% or less). If the tensile elongation difference ΔL is larger than 68%, the anisotropy of deformation of the mesh woven fabric tends to be strong. Therefore, in order to isotropically deform the mesh woven fabric, it is preferable to set the tensile elongation difference ΔL to 68% or less. From the viewpoint of more isotropically deforming the mesh woven fabric, the tensile elongation difference ΔL is preferably 55% or less (that is, 0% or more and 55% or less).

[0050] The mesh woven fabric is required to satisfy at least one of the following conditions: the slope difference ΔSL is 62% or less, the tensile strength difference ΔS is 20% or less, and the tensile elongation difference ΔL is 68% or less. More specifically, it is acceptable to focus on any of the following: only one of the slope difference ΔSL, the tensile strength difference ΔS, and the tensile elongation difference ΔL, a combination of any two of the slope difference ΔSL, the tensile strength difference ΔS, and the tensile elongation difference ΔL, and all of the slope difference ΔSL, the tensile strength difference ΔS, and the tensile elongation difference ΔL.

[0051] The thermal deformation amount of the mesh woven fabric in each of the warp direction and the weft direction can be measured by using a thermomechanical analyzer (TMA). Then, as shown in the following formula (7), a "thermal deformation amount difference", which is an index related to a difference between the thermal deformation amount in the warp direction and the thermal deformation amount in the weft direction, can be determined.

[Mathematical formula 7]

$$\Delta D = \frac{|D1 - D2|}{|Dave|} \times 100 \cdots (7)$$

[0052] In the above formula (7), ΔD is the above-described thermal deformation amount difference [%], D1 is the thermal deformation amount [mm] in the warp direction, and D2 is the thermal deformation amount [mm] in the weft direction. The thermal deformation amounts D1 and D2 are negative values when the mesh woven fabric shrinks in the warp direction and the weft direction, respectively, and are positive values when the mesh woven fabric stretches in the warp direction and the weft direction, respectively. Dave is an average of the thermal deformation amounts D1 and D2 (Dave = (D1 + D2)/2). According to the above formula (7), the thermal deformation amount difference ΔD indicates the rate of (the absolute value of) the difference between the thermal deformation amounts D1 and D2 to the absolute value of the average Dave.

[0053] The thermal deformation amount difference ΔD is preferably 180% or less (that is, 0% or more and 180% or less). If the thermal deformation amount difference ΔD is larger than 180%, the anisotropy of deformation of the mesh woven fabric tends to be strong. Therefore, in order to isotropically deform the mesh woven fabric, it is preferable to set the thermal deformation amount difference ΔD to 180% or less. From the viewpoint of more isotropically deforming the mesh woven fabric, the thermal deformation amount difference ΔD is preferably 160% or less (that is, 0% or more and 160% or less).

[0054] The mesh woven fabric according to the present invention described above is suitable for use in various solvents and high-temperature environments. For example, the mesh woven fabric can be used in medical applications such as artificial skin, filtration applications, applications to supports such as membranes made of ion exchange resins, such as chlorine-resistant reverse osmosis membranes, applications to various structural materials, electrochemical applications, and supports of membranes, such as humidified membranes, antifogging membranes, antistatic membranes, deoxygenated membranes, membranes for solar cells, and gas barrier membranes. In particular, it is preferable to use the mesh woven fabric in electrochemical applications, such as a support of an electrolyte membrane or a diaphragm used in a solid polymer fuel cell, a redox flow battery, an electrochemical hydrogen pump, a water electrolysis device, an alkaline water electrolysis type or solid polymer electrolyte membrane type hydrogen production device, a chlor-alkali electrolysis device, or the like.

Example 1

[0055] A mesh woven fabric was produced using a rapier loom. PPS monofilaments having a thread diameter of 56 [μm] were used as the warp thread and the weft thread that constituted the mesh woven fabric, and the mesh count was set to 150 [mesh/inch].

(Example 1)

[0056] A mesh woven fabric of Example 1 was produced by setting the tension per warp thread to 15 to 20 [cN] and setting the cross timing to 320[°].

(Example 2)

[0057] A mesh woven fabric of Example 2 was produced by setting the tension per warp thread to 15 to 20 [cN] and setting the cross timing to 330[°].

(Example 3)

[0058] A mesh woven fabric of Example 3 was produced by setting the tension per warp thread to 20 to 25 [cN] and setting the cross timing to 320[°].

(Example 4)

[0059] A mesh woven fabric of Example 4 was produced by setting the tension per warp thread to 20 to 25 [cN] and setting the cross timing to 330[°].

(Comparative Example)

[0060] A mesh woven fabric of Comparative Example was produced by setting the tension per warp thread to 25 to 30 [cN] and setting the cross timing to 340[°].

(Example 5)

[0061] PE monofilaments having a thread diameter of 70 [μm] were used as the warp thread and the weft thread that constituted the mesh woven fabric, and the mesh count was set to 70 [mesh/inch]. The tension per warp thread was set to 20 to 25 [cN], and the cross timing was set to 320[°]. The mesh woven fabric of Example 5 was produced under the same conditions as in Example 1 except for the above-described conditions.

(Example 6)

[0062] LCP monofilaments having a thread diameter of 24 [μm] were used as the warp thread and the weft thread that constituted the mesh woven fabric, and the mesh count was set to 150 [mesh/inch]. The tension per warp thread was set to 5 to 10 [cN], and the cross timing was set to 320[°]. The mesh woven fabric of Example 6 was produced under the same conditions as in Example 1 except for the above-described conditions.

(Example 7)

[0063] PEEK monofilaments having a thread diameter of 50 [μm] were used as the warp thread and the weft thread that constituted the mesh woven fabric, and the mesh count was set to 150 [mesh/inch]. The tension per warp thread was set to 20 to 25 [cN], and the cross timing was set to 320[°]. The mesh woven fabric of Example 7 was produced under the same conditions as in Example 1 except for the above-described conditions.

(Example 8)

[0064] PTFE monofilaments having a thread diameter of 60 [μm] were used as the warp thread and the weft thread that constituted the mesh woven fabric, and the mesh count was set to 80 [mesh/inch]. The tension per warp thread was set to 20 to 25 [cN], and the cross timing was set to 320[°]. The mesh woven fabric of Example 8 was produced under the same conditions as in Example 1 except for the above-described conditions.

(Measurement of Bending Angle)

[0065] Each of the mesh woven fabrics of Examples 1 to 8 and Comparative Example was cut at predetermined positions (positions at which bending angles θ1 and θ2 were to be measured), and the cut surfaces were observed with an optical microscope to measure the bending angle θ1 of the warp thread and the bending angle θ2 of the weft thread. The bending angle difference Δθ was determined according to the above formula (1). As for each of the bending angle θ1 of the warp thread and the bending angle θ2 of the weft thread, the average of the bending angles [°] at six intersections arbitrarily selected from the intersections of the mesh woven fabric was used.

(Measurement of Tensile Strength and Tensile Elongation)

[0066] From the mesh woven fabrics of Examples 1 to 8 and Comparative Example, mesh pieces having the same size in the warp direction and the weft direction (that is, 30 [mm] × 10 [mm]) were cut out, and were subjected to a tensile test using a tensile tester. The distance between the samples was 10 [mm], and the tensile speed was 10 [mm/min]. A tensile force in the warp direction was applied to the mesh pieces, and the tensile strength S1 and the tensile elongation L1 when the mesh pieces were broken were measured. In addition, a tensile force in the weft direction was applied to the mesh pieces, and the tensile strength S2 and the tensile elongation L2 when the mesh pieces were broken were measured.

[0067] After the measurement of the tensile strengths S1 and S2, the tensile strength difference ΔS [%] was determined according to the above formula (5). In addition, after the measurement of the tensile elongations L1 and L2, the tensile elongation difference ΔL [%] was determined according to the above formula (6). Meanwhile, a tensile strength-tensile elongation curve was obtained for each of the warp direction and the weft direction by the above-described tensile test, and the slopes SL1 and SL2 in elastic deformation regions (linear portions at the initial stage of tension) were determined as the slopes of the tensile strength-tensile elongation curves. In addition, after the measurement of the slopes SL1 and SL2, the slope difference ΔSL was determined according to the above formula (4).

(Measurement of Thermal Deformation Amount)

[0068] From the mesh woven fabrics of Examples 1 to 8 and Comparative Example, mesh pieces having the same size in the warp direction and the weft direction (that is, 15 [mm] × 5 [mm]) were cut out, and the thermal deformation amount of the mesh pieces (distance between chucks was 10 [mm]) was measured using a thermomechanical analyzer. Specifically, the thermal deformation amount in the warp direction and the thermal deformation amount in the weft direction of the mesh pieces were measured. As for the measurement conditions, the temperature was raised from 30[°C] to 250[°C] at a heating rate of 10[°C/min] under a tensile load of 50 mN/5 mm under the atmosphere. Then, the thermal deformation amount when the temperature was 125[°C] was measured.

[0069] The results of the above-described measurement are shown in Table 1.

[Table 1]

	Example 1	Example 2	Example 3	Example 4	Example 5	Example 6	Example 7	Example 8	Comparative Example
Tension of warp thread [cN/thread]	15-20	15-20	20-25	20-25	20-25	5-10	20-25	20-25	25-30
Cross timing [°]	320	330	320	330	320	320	320	320	340
Bending angle θ1 [°] of warp thread	144	147	158	160	137	171	143	140	157
Bending angle θ2 [°] of weft thread	163	145	161	135	143	165	154	151	128
Bending angle difference Δθ [%]	12.4	1.4	1.9	16.9	4.3	3.6	7.4	7.6	20.4
Tensile strength difference ΔS [%]	0	1.9	16.7	17.8	1.7	2.0	7.1	5.3	20.2
Tensile elongation difference ΔL [%]	16.0	30.8	6.6	40.4	12.9	9.0	31.3	20.2	68.6
Slope difference ΔSL [%]	52.6	46.2	7.4	23.8	19.8	8.7	52.1	15.2	63.0
Thermal deformation amount difference ΔD [%]	103.6	55.2	21.7	152.5	53.3	15.3	64.4	25.6	181.9

[0070] According to Examples 1 to 8, when the bending angle difference $\Delta\theta$ was set to 20% or less, all of the tensile strength difference ΔS, the tensile elongation difference ΔL, the slope difference ΔSL, and the thermal deformation amount difference ΔD were smaller than in Comparative Example in which the bending angle difference $\Delta\theta$ was set to more than 20%. The tensile strength difference ΔS, the tensile elongation difference ΔL, and the slope difference ΔSL were smaller in Examples 1 to 8 than in Comparative Example. Therefore, it can be understood that the mesh woven fabrics of Examples 1 to 8 are easily isotropically deformed by an external load (external force). In addition, the thermal deformation amount difference ΔD was smaller in Examples 1 to 8 than in Comparative Example. Therefore, it can be understood that the mesh woven fabrics of Examples 1 to 8 are easily isotropically deformed by an external load (heat).

[0071] As can be understood from Examples 1 to 8 and Comparative Example described above, the bending angle difference was further reduced by further reducing the tension of the warp thread and the cross timing. However, if the tension of the warp thread and the cross timing are too small, a defect occurs in the weaving performance. Thus, it is necessary to adjust the tension of the warp thread and the cross timing within a range in which no defect occurs in the weaving performance.

Reference Signs List

[0072]

1 Warp yarn
2a, 2b, 2c Weft yarn
P1, P2, P3 Reference point
L1, L2 Straight line

Claims

1. A mesh woven fabric comprising a warp thread and a weft thread, wherein

a bending angle of the warp thread and a bending angle of the weft thread at an intersection where the warp thread and the weft thread intersect each other are different from each other, and
a rate of an absolute value of a bending angle difference between the warp thread and the weft thread to an average of the bending angle of the warp thread and the bending angle of the weft thread is 20% or less.

2. The mesh woven fabric according to claim 1, which satisfies at least one of conditions described below:

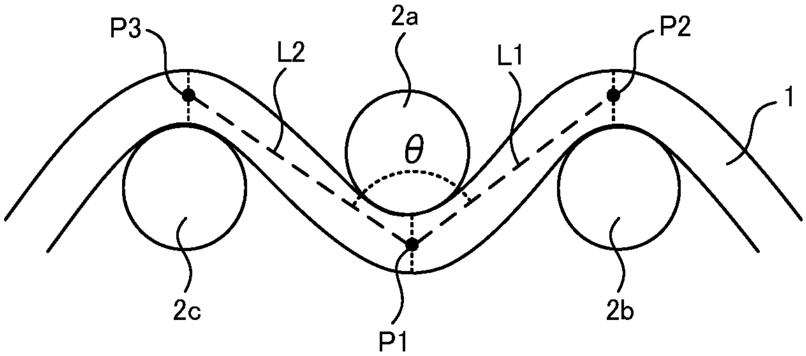
a rate of an absolute value of a tensile strength difference between a warp direction and a weft direction to an average of a tensile strength in the warp direction and a tensile strength in the weft direction is 20% or less;
a rate of an absolute value of a tensile elongation difference between the warp direction and the weft direction to an average of a tensile elongation in the warp direction and a tensile elongation in the weft direction is 68% or less; and
in curves showing a relation between a tensile load and a tensile elongation percentage, with respect to slopes in elastic deformation regions of the curves, a rate of an absolute value of a slope difference between the warp direction and the weft direction to an average of a slope for the warp direction and a slope for the weft direction is 62% or less.

3. The mesh woven fabric according to claim 1 or 2, wherein a rate of an absolute value of a thermal deformation amount difference between a warp direction and a weft direction to an average of a thermal deformation amount in the warp direction and a thermal deformation amount in the weft direction is 180% or less.

4. The mesh woven fabric according to claim 1, wherein at least one of the warp thread and the weft thread is a synthetic fiber.

5. The mesh woven fabric according to claim 4, wherein the synthetic fiber is a PE fiber, a PTFE fiber, a PPS fiber, an LCP fiber, or a PEEK fiber.

FIG.1



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2023/018561

A. CLASSIFICATION OF SUBJECT MATTER

D03D 9/00(2006.01)i; ***D03D 1/00***(2006.01)i; ***D03D 15/283***(2021.01)i
FI: D03D9/00; D03D1/00 Z; D03D15/283

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

D03D9/00; D03D1/00; D03D15/283

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2023
Registered utility model specifications of Japan 1996-2023
Published registered utility model applications of Japan 1994-2023

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 08-199448 A (TORAY IND INC) 06 August 1996 (1996-08-06) claims, paragraphs [0001], [0022], [0040], [0042], [0043], [0050]-[0068], examples	1-5
A	JP 2008-248396 A (TORAY IND INC) 16 October 2008 (2008-10-16) claims, examples, entire text	1-5
A	JP 2009-074215 A (TORAY IND INC) 09 April 2009 (2009-04-09) claims, examples, entire text	1-5
A	CN 113308776 A (LUTHAI TEXTILE CO., LTD.) 27 August 2021 (2021-08-27) claims, examples, entire text	1-5
A	JP 2000-273742 A (GOKASHO ORIMONO KK) 03 October 2000 (2000-10-03) claims, examples, entire text	1-5

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
11 July 2023	**25 July 2023**

Name and mailing address of the ISA/JP	Authorized officer
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2023/018561

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 08-199448 A	06 August 1996	(Family: none)	
JP 2008-248396 A	16 October 2008	(Family: none)	
JP 2009-074215 A	09 April 2009	(Family: none)	
CN 113308776 A	27 August 2021	(Family: none)	
JP 2000-273742 A	03 October 2000	(Family: none)	

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