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(54) **METHOD OF MANUFACTURING BATTERY**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 496 days.

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(30) **Foreign Application Priority Data**

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(57) **ABSTRACT**

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B65H 39/16 (2006.01)

H01M 10/0525 (2010.01)

(52) **U.S. Cl.**

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(2013.01); **H01M 10/0525** (2013.01); **B65H**
2301/5151 (2013.01); **B65H 2406/33**
(2013.01); **Y10T 29/49108** (2015.01)

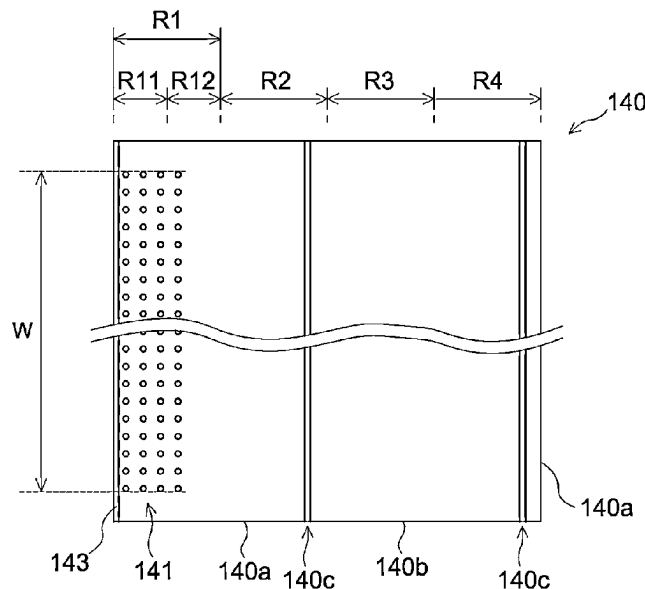
(58) **Field of Classification Search**

CPC H01M 10/0587; H01M 10/0409; H01M
10/0431; Y10T 29/49108

USPC 29/623.1, 623.3, 732
See application file for complete search history.

A method of manufacturing a battery including a wound electrode assembly in which a first separator, a negative electrode plate, a second separator, and a positive electrode plate are wound together is disclosed. The method includes step (A) of suction-attaching the first separator to a winding core, and step (B) of winding the first separator on the winding core. The winding core includes a plurality of suction holes for suction-attaching the first separator. When the outer circumference of the winding core is divided into four equal parts and the four equal parts are defined respectively as first to fourth regions starting from a position that faces a starting end of winding of the first separator, greater than or equal to 80%, by aperture area ratio, of the suction holes are formed in the first region.

12 Claims, 9 Drawing Sheets



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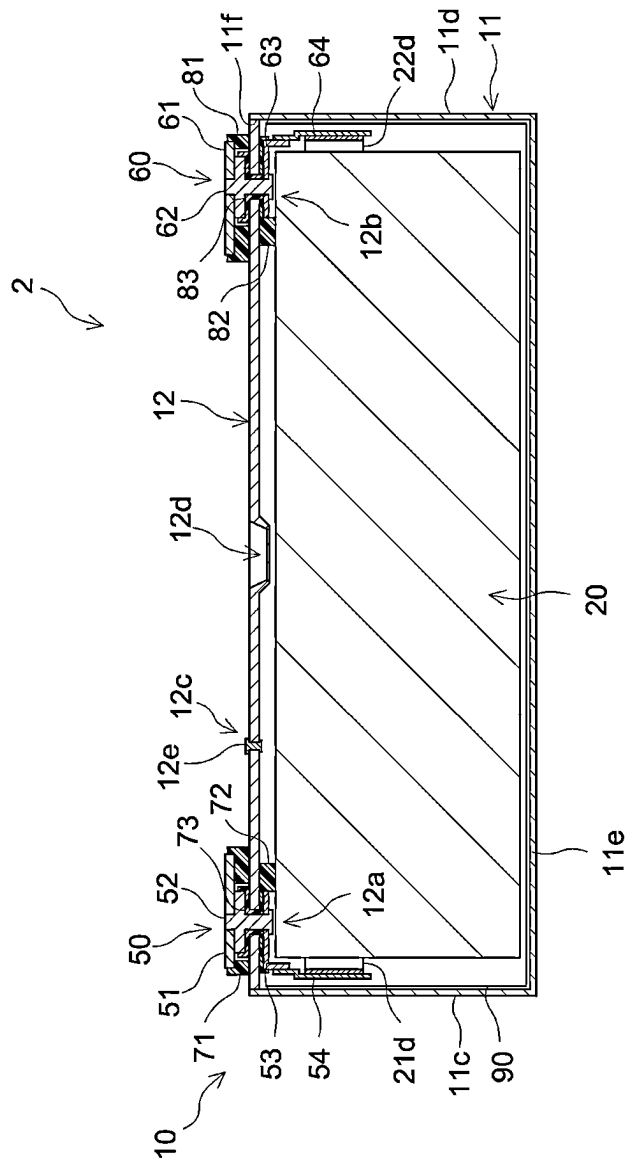


FIG. 1

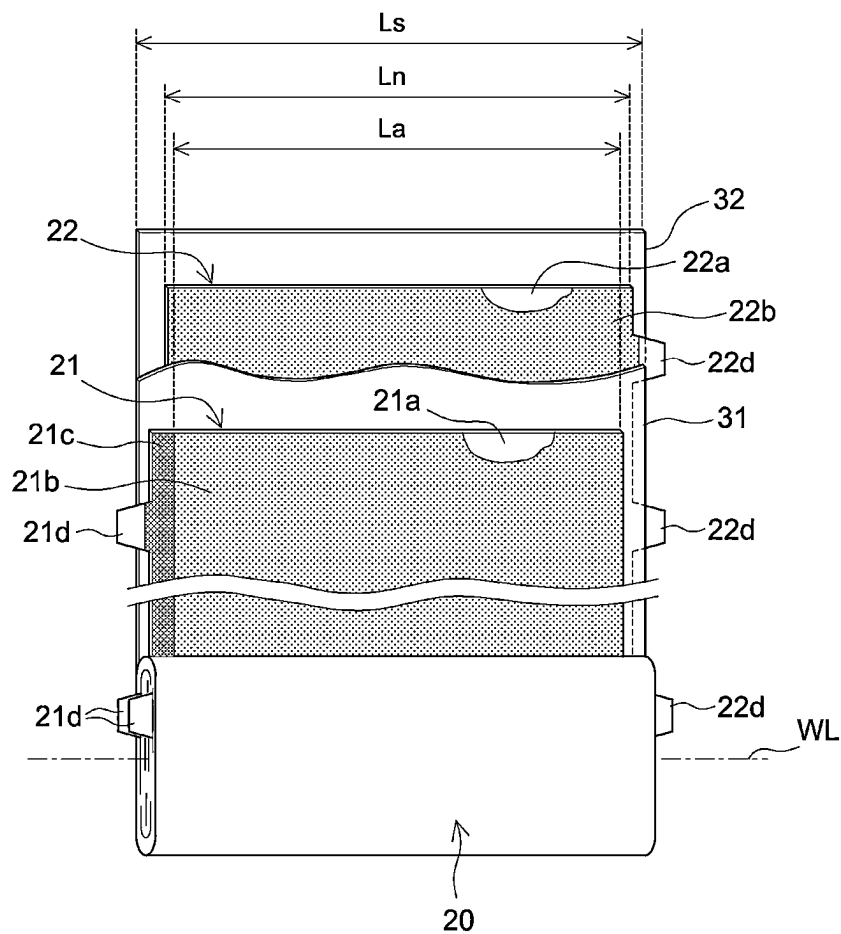


FIG.2

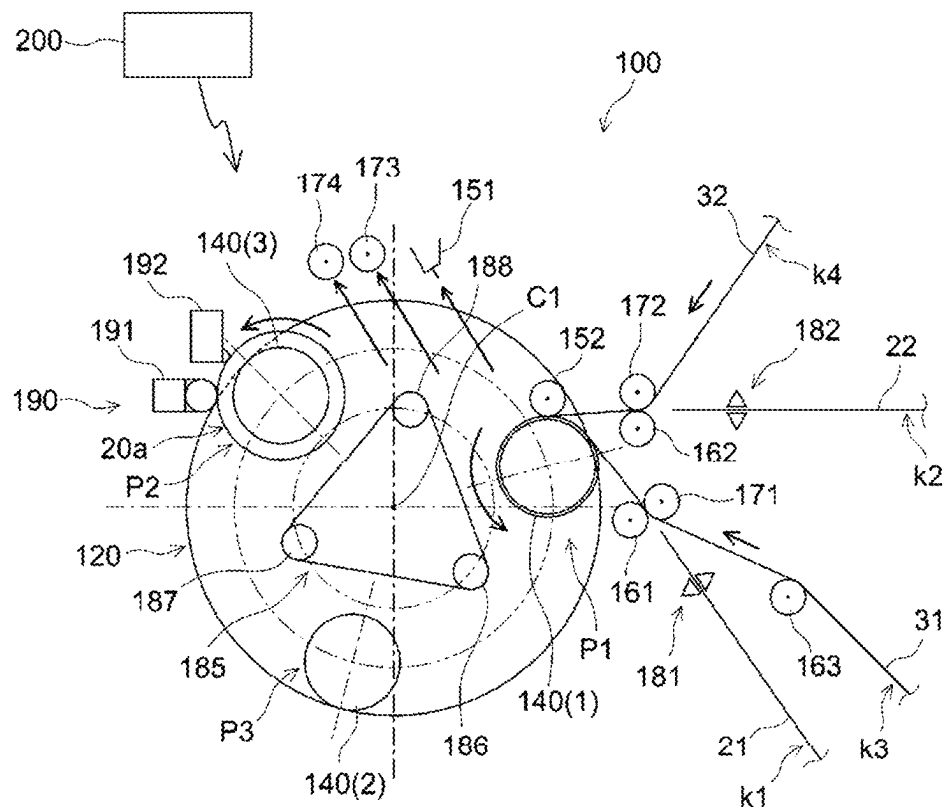


FIG.3

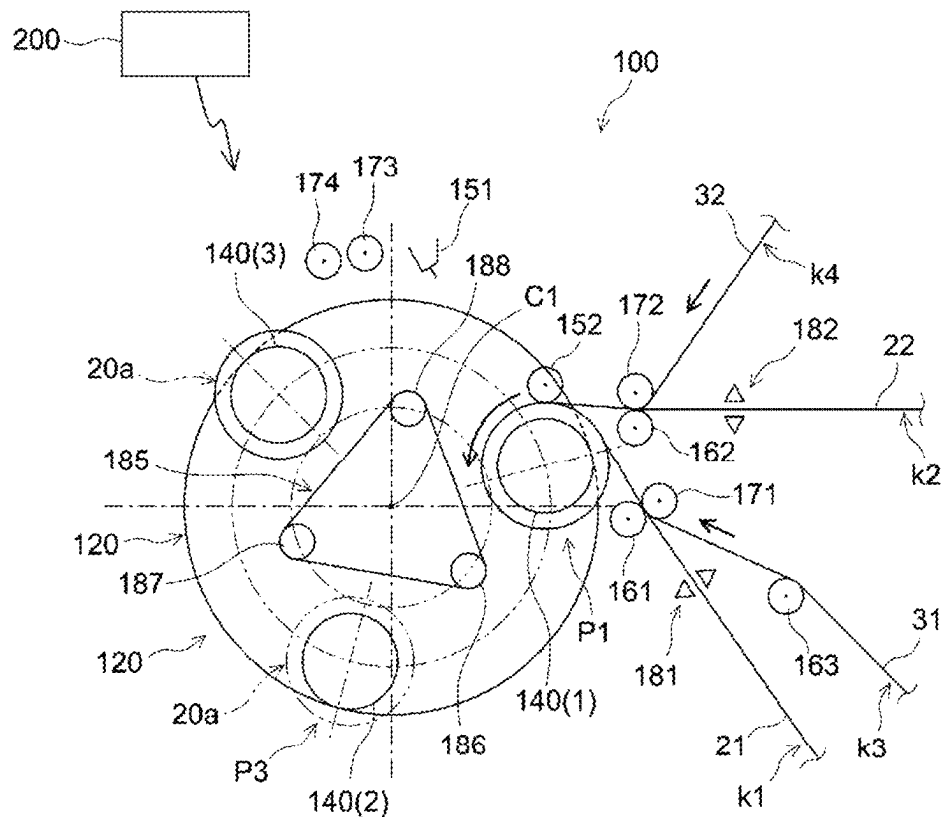


FIG.4

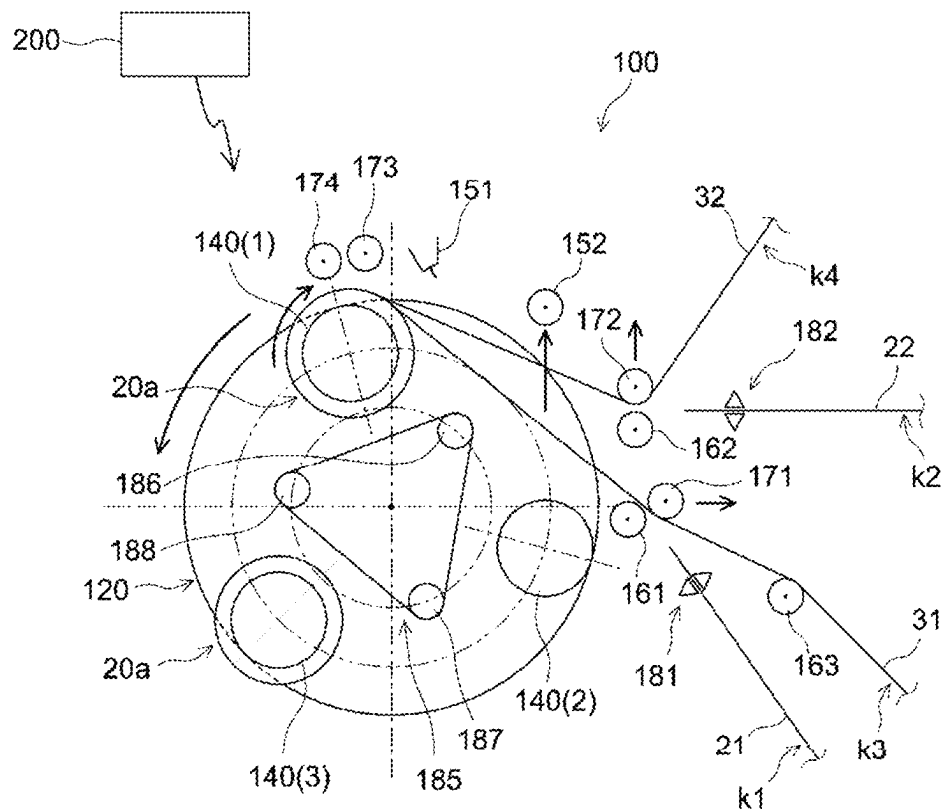


FIG.5

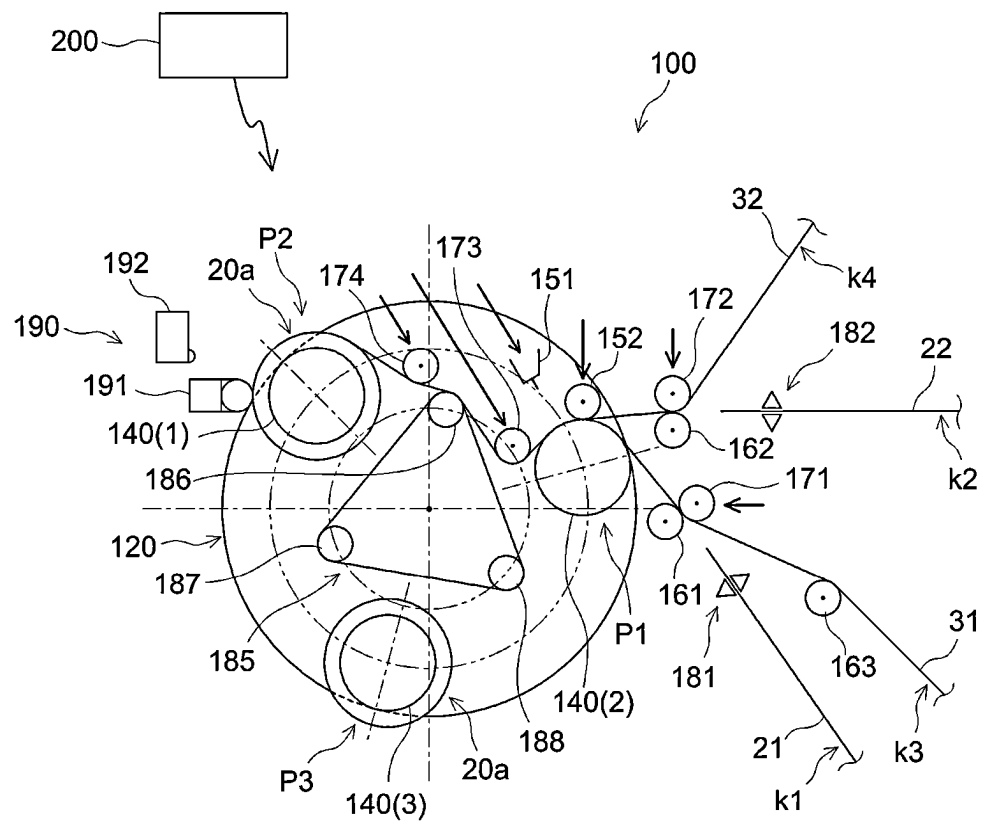


FIG.6

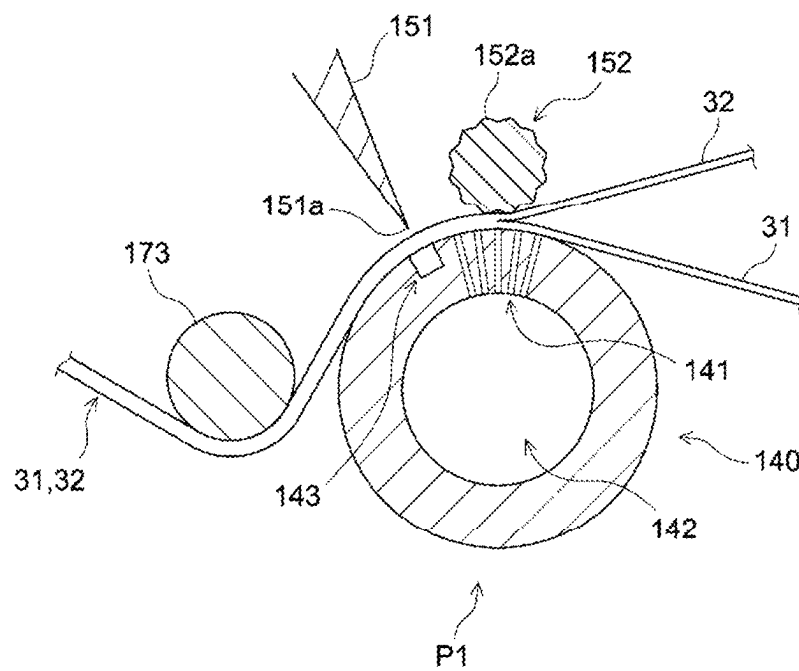


FIG. 7

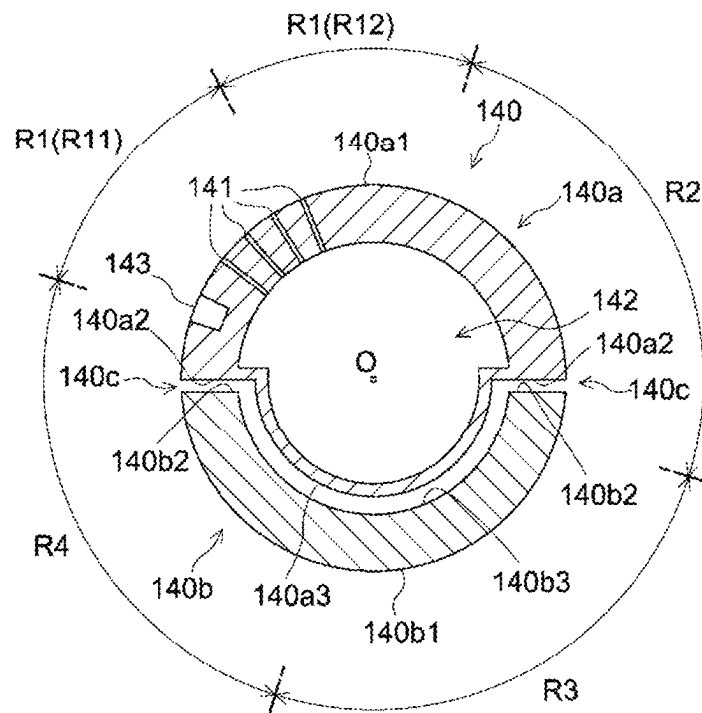


FIG. 8

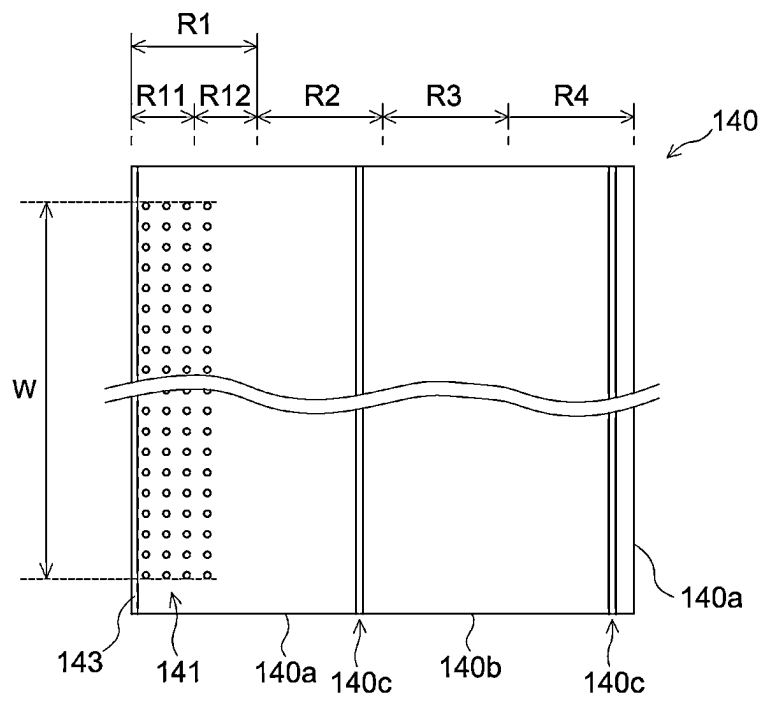


FIG.9

METHOD OF MANUFACTURING BATTERY

CROSS REFERENCE TO RELATED APPLICATIONS

The present application claims priority from Japanese Patent Application No. 2021-131371 filed on Aug. 11, 2021, which is incorporated by reference herein in its entirety.

BACKGROUND

The present invention relates to a method of manufacturing a battery.

JP 2006-216520 A discloses a winding core used for a winding apparatus that is used in manufacturing a strip-shaped material winding body such as a secondary battery. The winding core disclosed in the publication is provided with a plurality of suction/discharge holes formed at regular intervals in its outer surface. Because of the suction/discharge holes, the winding core is able to cause a separator or the like to be suction-attached to the winding core. The use of such a winding core makes it possible to wind a battery element without forming a folded portion in a material of the battery element. This makes it possible to eliminate a subsequent process, and accordingly, it is possible to reduce the mechanisms and parts and thus reduce costs.

SUMMARY

The present inventors believe that it is desirable to improve production efficiency in manufacturing a wound electrode assembly. According to the knowledge of the present inventors, there is room for improvement in the method of winding a negative electrode plate, a positive electrode plate, and separators in manufacturing the wound electrode assembly.

The present disclosure discloses a method of manufacturing a battery including a wound electrode assembly in which a first separator, a negative electrode plate, a second separator, and a positive electrode plate are wound together. An embodiment of the method of manufacturing the battery includes step (A) of suction-attaching the first separator to a winding core, and step (B) of winding the first separator on the winding core. The winding core includes a plurality of suction holes for suction-attaching the first separator. Greater than or equal to 80% by aperture area ratio of the suction holes are formed in a first region of the winding core, wherein the first region is defined by dividing an outer circumferential surface of the winding core into four equal parts, the four equal parts respectively being first to fourth regions starting from a position of the winding core that faces a starting end of winding of the first separator of the wound electrode assembly. The above-described embodiment of the method of manufacturing a battery makes it possible to improve production efficiency in manufacture of the wound electrode assembly.

An embodiment of the method of manufacturing the battery may further include step (C) of cutting the first separator and the second separator. It is also possible that, in step (C), the first separator and the second separator may be cut with the first separator and the second separator being wound on a circumferential region of 15 degrees to 180 degrees of the other winding core that is different from the winding core onto which the first separator is wound in step (B).

It is also possible that, in step (C), the first separator may be cut, with the first separator being in contact with the other

winding core that is different from the winding core onto which the first separator is wound in step (B) in an upstream side and a downstream side of a cut position at which the first separator is cut in a transfer path of the first separator.

It is also possible that, in step (C), when cutting the first separator and the second separator, the first separator and the second separator may be pressed against the other winding core by a presser jig, the other winding core being different from the winding core onto which the first separator is wound in step (B). The presser jig may be a roller including a plurality of protrusions formed on a surface thereof.

In step (C), the other winding core that is different from the winding core onto which the first separator is wound in step (B) may include a groove formed along an axial direction of the other winding core corresponding to a position of the other winding core at which the first separator and the second separator are cut.

In step (C), the first separator and the second separator may be cut by a blade that is movable toward the other winding core that is different from the winding core onto which the first separator is wound in step (B).

The winding core may be divided into at least two parts in a radial direction of the winding core, and the first separator may be suction-attached to a portion of the divided parts of the winding core only.

A suction hole formation region, in which the plurality of suction holes are formed, has a width less than a width of the first separator.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a vertical sectional view of a battery 2.

FIG. 2 is a schematic view of a wound electrode assembly 20.

FIG. 3 is a schematic view of a winding machine 100.

FIG. 4 is another schematic view of the winding machine 100.

FIG. 5 is still another schematic view of the winding machine 100.

FIG. 6 is still another schematic view of the winding machine 100.

FIG. 7 is a cross-sectional view schematically illustrating a winding core 140 disposed at a first position P1.

FIG. 8 is a cross-sectional view of the winding core 140.

FIG. 9 is a schematic view illustrating the structure of the outer circumferential surface of the winding core 140.

DETAILED DESCRIPTION

Embodiments of the invention according to the present disclosure will be described hereinbelow. It should be noted, however, that the disclosed embodiments are, of course, not intended to limit the invention. The present invention is not limited to the embodiments described herein unless specifically stated otherwise. The drawings are depicted schematically and do not necessarily accurately depict actual objects. The features and components that exhibit the same effects are designated by the same reference symbols as appropriate, and the description thereof will not be repeated.

FIG. 1 is a vertical sectional view of a battery 2. FIG. 1 schematically shows the battery 2 from which the front-side wider surface of a battery case 10 is virtually removed so that the inside of the battery case 10 can be seen. The battery 2 is one embodiment of the battery produced by the manufacturing method disclosed herein. The battery 2 includes a wound electrode assembly 20 accommodated in a battery case 10. It should be noted that the embodiments of the

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battery manufactured by the method disclosed herein are not limited to the one shown in FIG. 1.

Battery 2

The battery 2 shown in FIG. 1 is a horizontally elongated prismatic battery. As illustrated in FIG. 1, the battery 2 includes the battery case 10, the wound electrode assembly 20, a positive electrode terminal 50, and a negative electrode terminal 60. The battery case 10 includes an outer container 11 and a sealing plate 12.

Outer Container 11

The outer container 11 is a closed-bottom prismatic case having a horizontally elongated rectangular-shaped enclosing space. The outer container 11 mainly encloses the wound electrode assembly 20. The outer container 11 includes a substantially rectangular-shaped bottom surface 11e, a pair of opposing wider surfaces 11a and 11b (not shown) provided along the longer sides of the bottom surface 11e, and a pair of opposing narrower surfaces 11c and 11d provided along the shorter sides of the bottom surface 11e. An open end 11f is formed facing the bottom surface 11e to accommodate the wound electrode assembly 20. The sealing plate 12 is attached to the open end 11f.

Sealing Plate 12

The sealing plate 12 is fitted to the open end 11f of the battery case 10. The sealing plate 12 is composed of a substantially rectangular-shaped plate material that can be fitted to the open end 11f of the outer container 11. The sealing plate 12 is a substantially rectangular-shaped plate material. In the sealing plate 12, a mounting hole 12a for mounting a positive electrode terminal 50 is formed near one longitudinal end thereof, and a mounting hole 12b for mounting a negative electrode terminal 60 is formed near the opposite end.

A filling port 12c and a gas vent valve 12d are provided at a central portion of the sealing plate 12. The filling port 12c is a through hole provided for filling a non-aqueous electrolyte solution into the interior of the battery case 10 that has been hermetically sealed. After filling the non-aqueous electrolyte solution, the filling port 12c is sealed with a sealing member 12e fitted therein. The gas vent valve 12d is a thinned portion that is designed to rupture (i.e., to open) when a large amount of gas is generated inside the battery case 10, so as to expel the gas.

For the non-aqueous electrolyte solution, it is possible to use any non-aqueous electrolyte solution used for conventionally known secondary batteries without any particular limitation. For example, the non-aqueous electrolyte solution may be prepared by dissolving a supporting salt into a non-aqueous solvent. Examples of the non-aqueous solvent include carbonate-based solvents, such as ethylene carbonate, dimethyl carbonate, and ethyl methyl carbonate. Examples of the supporting salt include fluorine-containing lithium salts, such as LiPF₆.

Positive Electrode Terminal 50 and Negative Electrode Terminal 60

The positive electrode terminal 50 and the negative electrode terminal 60 are attached to the sealing plate 12. The wound electrode assembly 20 is enclosed in the outer container 11, with the wound electrode assembly 20 being attached to the positive electrode terminal 50 and the negative electrode terminal 60. The positive electrode terminal 50 includes an external terminal 51, a shaft member 52, an internal terminal 53, a current collecting member 54, a first insulator 71, a second insulator 72, and a gasket 73. The negative electrode terminal 60 includes an external terminal 61, a shaft member 62, an internal terminal 63, a current collecting member 64, a first insulator 81, a second insulator

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82, and a gasket 83. The first insulators 71, 81, the second insulators 72, 82, and the gaskets 73, 83 are each composed of an insulating material. The first insulators 71, 81 and the second insulators 72, 82 are each composed of a resin having required rigidity. The gaskets 73 and 83 are members that are fitted respectively to the mounting holes 12a and 12b of the sealing plate 12 and each have required flexibility.

The respective shaft members 52 and 62 of the positive electrode terminal 50 and the negative electrode terminal 60 are fitted to the mounting holes 12a and 12b of the sealing plate 12 with the respective gaskets 73 and 83 interposed therebetween. The external terminals 51 and 61 are attached to the outside of the sealing plate 12 with the first insulators 71 and 81 interposed therebetween. Each of the external terminals 51 and 61 includes a mounting hole, and is fitted to the outer end of each of the shaft members 52 and 62. The internal terminals 53 and 63 are attached to the inside of the sealing plate 12 with the second insulators 72 and 82 interposed therebetween. Each of the internal terminals 53 and 63 includes a mounting hole, and is fitted to the inner end of each of the shaft members 52 and 62. The inner end of each of the shaft members 52 and 62 is press-fitted to the circumference of the mounting hole of each of the internal terminals 53 and 63. Each of the current collecting members 54 and 64 is attached to one end of each of the internal terminals 53 and 63.

Thus, the positive electrode terminal 50 and the negative electrode terminal 60 are attached to the sealing plate 12, with the positive electrode terminal 50 and the negative electrode terminal 60 being electrically insulated by the first insulators 71, 81, the second insulators 72, 82, and the interposed gaskets 73, 83, and with hermeticity being ensured. Also, an electrically conductive path is formed by the external terminals 51, 61, the shaft members 52, 62, the internal terminals 53, 63, and the current collecting members 54, 64. The wound electrode assembly 20 is fitted to the current collecting members 54 and 64. With the wound electrode assembly 20 being attached to the sealing plate 12 in this way, the wound electrode assembly 20 is enclosed in the outer container 11. It is also possible that a plurality of wound electrode assemblies 20 may be attached to one sealing plate 12. It is also possible that a plurality of wound electrode assemblies 20 may be accommodated in one battery case 10.

Wound Electrode Assembly 20

FIG. 2 is a schematic view of the wound electrode assembly 20. FIG. 2 shows the wound electrode assembly 20 one end of which is unrolled. In the wound electrode assembly 20, for example, as illustrated in FIG. 2, a positive electrode plate 21, a first separator 31, a negative electrode plate 22, and a second separator 32, each of which is in a long strip shape, are stacked successively with their longitudinal axes aligned with each other and are wound around a winding axis WL that is set in a widthwise direction.

The positive electrode plate 21 includes a positive electrode substrate 21a, a positive electrode active material layer 21b, a protective layer 21c, and tabs 21d. The positive electrode substrate 21a is the substrate material of the positive electrode plate 21. The positive electrode substrate 21a is formed of a predetermined metal foil (for example, aluminum foil). The positive electrode active material layer 21b is formed with a constant width on both faces of the positive electrode substrate 21a except for one lateral end portion thereof. The protective layer 21c is formed on both sides of the positive electrode plate 21. The protective layer 21c is formed in a portion of the positive electrode substrate 21a that is other than the portion on which the positive

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electrode active material layer **21b** is formed. In addition, the tabs **21d** protruding in a lateral direction are formed at a lateral end of the positive electrode substrate **21a** on which the protective layer **21c** is formed. The tabs **21d** with a predetermined width protrude partially from the lateral end on which the protective layer **21c** is formed, so that the positive electrode substrate **21a** is exposed.

The positive electrode active material layer **21b** is a layer containing a positive electrode active material. In a lithium-ion secondary battery, for example, the positive electrode active material is a material that is capable of releasing lithium ions during charge and absorbing lithium ions during discharge, such as lithium-transition metal composite materials. Generally, other than the lithium-transition metal composite materials, various materials have been proposed for use as the positive electrode active material, and the positive electrode active material is not limited to any particular material.

Suitable examples of the positive electrode active material include, for example, lithium-transition metal composite oxides. Among the lithium-transition metal composite oxides, particularly suitable are lithium-transition metal composite oxides containing at least one transition metal selected from the group consisting of nickel (Ni), cobalt (Co), and manganese (Mn). Specific examples include lithium-nickel-cobalt-manganese composite oxide (NCM), lithium-nickel composite oxide, lithium-cobalt composite oxide, lithium-manganese composite oxide, lithium-nickel-manganese composite oxide, lithium-nickel-cobalt-aluminum composite oxide (NCA), and lithium-iron-nickel-manganese composite oxide. Suitable examples of lithium-transition metal composite oxides that do not contain Ni, Co, or Mn include lithium-iron-phosphate composite oxide (LFP).

It should be noted that the term "lithium-nickel-cobalt-manganese composite oxide" in the present description means to include oxides that contain additional elements other than the main constituent elements (Li, Ni, Co, Mn, and O). Examples of such additional elements include transition metal elements and main group metal elements, such as Mg, Ca, Al, Ti, V, Cr, Si, Y, Zr, Nb, Mo, Hf, Ta, W, Na, Fe, Zn, and Sn. The additional elements may include metalloid elements, such as B, C, Si, and P, and non-metallic elements, such as S, F, Cl, Br, and I. The positive electrode active material layer **21b** may contain addition agents other than the positive electrode active material. Examples of such addition agents may include conductive agents and binders. Examples of the conductive agents include carbon materials such as acetylene black (AB). Examples of the binders include resin binders such as polyvinylidene fluoride (PVdF). When the total solid content of the positive electrode active material layer **21b** is 100 mass %, the content of the positive electrode active material may be approximately greater than or equal to 80 mass %, and typically greater than or equal to 90 mass %.

The protective layer **21c** is a layer configured to reduce electrical conductivity. Such a protective layer **21c** is provided in a region adjacent to an edge portion of the positive electrode active material layer **21b**. The protective layer **21c** may serve to prevent the positive electrode substrate **21a** and the negative electrode active material layer **22b** from coming into contact with each other directly and causing internal short circuits when either of the separators **31** and **32** is damaged. For the protective layer **21c**, it is possible to form a layer containing electrically insulative ceramic particles, for example. Examples of such ceramic particles include: inorganic oxides, such as alumina (Al₂O₃), magnesia

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(MgO), silica (SiO₂), and titania (TiO₂); nitrides, such as aluminum nitride and silicon nitride; metal hydroxides, such as calcium hydroxide, magnesium hydroxide, and aluminum hydroxide; clay minerals, such as mica, talc, boehmite, zeolite, apatite, and kaoline; and glass fibers. Taking electrical insulation and heat resistance into consideration, suitable among them are alumina, boehmite, aluminum hydroxide, silica, and titania. The protective layer **21c** may contain a binder for fixing the ceramic particles onto the surface of the positive electrode substrate **21a**. Examples of such a binder include resin binders such as polyvinylidene fluoride (PVdF). The protective layer **21c** may contain a trace amount of conductive agent (for example, a carbon material such as carbon black). By adding the conductive agent, the protective layer may be made to have slight electrical conductivity. The amount of the conductive agent to be added may be adjusted to an amount that can obtain required electrical conductivity. Note that the protective layer is not an essential constituent component of the positive electrode plate. That is, the secondary battery disclosed herein may also use a positive electrode plate that is not provided with a protective layer.

The negative electrode plate **22** includes a negative electrode substrate **22a**, a negative electrode active material layer **22b**, and tabs **22d**. The negative electrode substrate **22a** is the substrate material of the negative electrode plate **22**. The negative electrode substrate **22a** is formed of a predetermined metal foil (for example, copper foil). The negative electrode active material layer **22b** is formed on both sides of the negative electrode substrate **22a** substantially along the entire width of the negative electrode substrate **22a**. The negative electrode substrate **22a** is provided with the tabs **22d** protruding from one lateral end thereof. The tabs **22d** with a predetermined width protrude partially from the one lateral end of the negative electrode substrate **22a**.

The negative electrode active material layer **22b** is a layer containing a negative electrode active material. The negative electrode active material is not particularly limited, as long as the negative electrode active material is able to reversibly absorb and release charge carriers in relation to the above-described positive electrode active material. Examples of the negative electrode active material include carbon materials and silicon based materials. The carbon materials may be, for example, graphite, hard carbon, soft carbon, amorphous carbon, and the like. It is also possible to use amorphous carbon-coated graphite, in which the surface of graphite is coated with amorphous carbon, or the like. Examples of the silicon based materials include silicon and silicon oxide (silica). The silicon based materials may also contain other metal elements (such as alkaline-earth metals) and oxides thereof. The negative electrode active material layer **22b** may contain addition agents other than the negative electrode active material. Examples of such addition agents may include binders and thickening agents. Specific examples of the binders include rubber-based binders, such as styrene-butadiene rubber (SBR). Specific examples of the thickening agents include carboxymethylcellulose (CMC). When the total solid content of the negative electrode active material layer **22b** is 100 mass %, the content of the negative electrode active material is approximately greater than or equal to 30 mass %, and typically greater than or equal to 50 mass %. The negative electrode active material may account for greater than or equal to 80 mass %, or greater than or equal to 90 mass %, of the negative electrode active material layer **22b**.

Each of the separators **31** and **32** may be formed of, for example, an electrolyte permeable porous resin sheet with

required heat resistance. Various embodiments of the separators **31** and **32** have been proposed, and the separators **31** and **32** are not particularly limited. Suitable examples of the separators **31** and **32** include a separator including a porous substrate layer made of resin such as polyolefin resin [for example, polyethylene (PE) or polypropylene (PP)]. It is also possible that a coat layer may be formed on one side or both sides of the porous substrate layer as appropriate. The coat layer may include an adhesive layer and a porous surface layer containing electrically insulative inorganic material. The porous surface layer is excellent in heat resistance and is therefore able to prevent shrinkage and breakage of the separators **31** and **32** due to temperature increase. Examples of the inorganic materials for the porous surface layer include ceramic particles of alumina, boehmite, aluminum hydroxide, titania, and the like. In addition, the porous surface layer contains a binder for binding the ceramic particles. The binder may be resin binders such as polyvinylidene fluoride (PVDF) and acrylic resins. It should be noted that the two separators **31** and **32** used in the present embodiment may be constructed of either the same or different materials.

As illustrated in FIG. 2, the negative electrode active material layer **22b** of the negative electrode plate **22** may cover the positive electrode active material layer **21b** of the positive electrode plate **21** with the separators **31** and **32** interposed therebetween. The separators **31** and **32** may further cover the positive electrode active material layer **21b** of the positive electrode plate **21** and the negative electrode active material layer **22b** of the negative electrode plate **22**. Although not shown in the drawings, the lengths of the positive electrode plate **21**, the negative electrode plate **22**, and the separators **31**, **32** may satisfy the relation: the length of separators **31**, **32** > the length of negative electrode plate **22** > the length of positive electrode plate **21**. The width L_a of the positive electrode active material layer **21b**, the width L_n of the negative electrode active material layer **22b**, and the width L_s of the separators **31**, **32** may satisfy the relation: $L_s > L_n > L_a$. In the portion in which the positive electrode plate **21** and the negative electrode plate **22** are stacked, a portion on which the positive electrode active material layer **21b** is formed is covered by the negative electrode active material layer **22b**. In addition, the protective layer **21c** is formed on a portion of the positive electrode plate **21** in which the negative electrode active material layer **22b** overlaps the positive electrode plate **21** but does not oppose the positive electrode active material layer **21b**.

As illustrated in FIG. 2, the tabs **21d** of the positive electrode plate **21** protrude from one lateral end of the separators **31** and **32**. The positive electrode plate **21** is provided with a plurality of tabs **21d** arranged along the longitudinal axis at a predetermined pitch. The tab **22d** of the negative electrode plate **22** protrude from the other lateral end of the separators **31** and **32**. The negative electrode plate **22** is provided with a plurality of tabs **22d** arranged along the longitudinal axis at a predetermined pitch. The plurality of tabs **21d** of the positive electrode plate **21** and the plurality of tabs **22d** of the negative electrode plate **22** are arranged at a predetermined pitch so that they are located generally at the matching positions after the positive electrode plate **21** and the negative electrode plate **22** are wound into the wound electrode assembly **20**. The tabs **21d** of the positive electrode plate **21** and the tabs **22d** of the negative electrode plate **22** may be formed at the respective stages where the positive electrode plate **21** and the negative electrode plate **22** are prepared. It is also possible that the tabs **21d** of the positive electrode plate **21** and the tabs **22d** of the negative

electrode plate **22** may be formed by cutting out portions of the electrode plates after the wound electrode assembly **20** has been wound.

As illustrated in FIGS. 1 and 2, the wound electrode assembly **20** is placed into the outer container **11** from the open end **11f**, to which the sealing plate **12** is to be fitted. For this reason, the wound electrode assembly **20** is in a flat shape corresponding to the shape of the open end **11f**. When preparing the wound electrode assembly **20** in such a fashion, the wound electrode assembly **20** may be wound on a flat-shaped mandrel. Alternatively, when preparing the wound electrode assembly **20**, the wound electrode assembly **20** may be wound on a cylindrical-shaped mandrel and thereafter press-formed into a flat shape. The wound electrode assembly **20** and the outer container **11** are electrically insulated from each other by an insulating sheet **90** made of resin and disposed between the wound electrode assembly **20** and the outer container **11**. The insulating sheet **90** is a resinous sheet and is bent into a box shape so as to surround the wound electrode assembly **20**. Note that FIG. 1 shows the battery **2** from which the front-side wider surface of the insulating sheet **90** is also removed.

Winding Machine 100

Next, a winding machine **100** will be described. FIGS. 3 to 6 each show a schematic view of the winding machine **100**. The winding machine **100** is an example of the winding machine that embodies a method of manufacturing a battery as disclosed herein. FIGS. 3 to 6 each show a view of a turret **120** portion of the winding machine **100**, which is viewed from the far end of a rotational axis **C1** of the turret **120**.

FIG. 3 illustrates a stand-by state, in which the winding machine **100** starts to newly wind a positive electrode plate **21** and a negative electrode plate **22**. FIG. 4 illustrates a state in which the positive electrode plate **21** and the negative electrode plate **22** are being newly wound by the winding machine **100**. FIG. 5 illustrates a state in which a winding core **140**, on which the positive electrode plate **21** and the negative electrode plate **22** have been wound, is moved from a first position **P1** to a second position **P2**. FIG. 6 illustrates a state in which the winding core **140**, on which the positive electrode plate **21** and the negative electrode plate **22** have been wound, is moved to the second position **P2**, another winding core is moved to the first position **P1**, and the separators **31** and **32** are cut.

As illustrated in FIG. 3, the winding machine **100** is an apparatus for winding the positive electrode plate **21**, the negative electrode plate **22**, and the separators **31** and **32**. The turret **120** is provided with a plurality of winding cores **140(1)-(3)**, around which a positive electrode plate **21**, a negative electrode plate **22**, and separators **31** and **32** are to be wound.

The winding machine **100** includes, as illustrated in FIG. 3, transfer paths **k1** to **k4**, a turret **120**, a plurality of winding cores **140(1)-(3)**, a cutter **151**, a presser roller **152**, a plurality of stationary rollers **161** to **163**, a plurality of movable rollers **171** to **174**, a first chuck **181**, a second chuck **182**, an index unit **185** provided on the turret **120**, index rollers **186** to **188** provided in the index unit **185**, a winding termination device **190**, and a controller **200**. The positive electrode plate **21**, the negative electrode plate **22**, and the separators **31** and **32** are prepared in such a condition that they are wound around respective reels (not shown) or the like. Each of the constituent components of the winding machine **100** may include a required actuator when appropriate. The controller **200** is configured to control various constituent components of the winding machine **100** so that required operations can be performed at predetermined

timing according to predetermined programs. The controller 200 may be embodied by a computer such as a microcontroller, for example.

Transfer Paths k1 to k4

The transfer path k1 is a path in which the positive electrode plate 21 is delivered from a reel toward the turret 120. The transfer path k2 is a path in which the negative electrode plate 22 is delivered from the reel toward the turret 120. The transfer path k3 is a path in which the first separator 31 is delivered from the reel toward the turret 120. The transfer path k4 is a path in which the second separator 32 is delivered from the reel toward the turret 120. The positive electrode plate 21, the negative electrode plate 22, the first separator 31, and the second separator 32 are each in a strip shape, and they are delivered along predetermined transfer paths k1 to k4, respectively. The transfer path k1 of the positive electrode plate 21 merges with the transfer path k3 of the first separator 31 before reaching the winding core 140 disposed at the first position P1. The transfer path k2 of the negative electrode plate 22 merges with the transfer path k4 of the second separator 32 before reaching the winding core 140 disposed at the first position P1. The transfer paths k1 to k4 may be provided with, for example, a dancer roller mechanism that takes up the slack in the positive electrode plate 21, the negative electrode plate 22, the first separator 31, and the second separator 32 that are delivered, a tensioner that adjusts their tensions, and the like, as appropriate. Turret 120

The turret 120 is a rotary disk the rotational axis of which is disposed at its center C1. A plurality (three in this embodiment) of winding cores 140 are disposed on the turret 120. The plurality of winding cores 140 are substantially cylindrical-shaped mandrels that are rotatable independently from each other. In this embodiment, the axes of the plurality of winding cores 140 are disposed so as to be parallel to the central axis of the turret 120. The turret 120 is provided with three winding cores 140, a first winding core 140(1), a second winding core 140(2), and a third winding core 140(3). The first winding core 140(1), the second winding core 140(2), and the third winding core 140(3) are disposed around the central axis of the turret 120 so as to be circumferentially equally spaced from each other. The first winding core to the third winding core 140(1)-(3) each have the same configuration. Although not shown in the drawings, the turret 120 is provided with a required actuator (for example, a servomotor) to rotate by an appropriate angle at appropriate timing.

A first position P1, a second position P2, a third position P3 are predetermined around the axis of the center C1 of the turret 120. In FIG. 3, the first winding core 140(1) is disposed at the first position P1, the third winding core 140(3) is disposed at the second position P2, and the second winding core 140(2) is disposed at the third position P3. The positions of the first winding core to the third winding core 140(1)-(3) are not fixed to the positions shown in FIG. 3. In this embodiment, the turret 120 rotates counterclockwise. The first winding core to the third winding core 140(1)-(3) also rotate counterclockwise. The first winding core to the third winding core 140(1)-(3) move successively from one position to another, from the first position P1, to the second position P2, and to the third position P3, due to rotation of the turret 120. Although not shown in the drawings, each of the first winding core to the third winding core 140(1)-(3) is provided with a required actuator (for example, a servomotor) to rotate at an appropriate speed at appropriate timing. Herein, each of the first winding core to the third winding core 140(1)-(3) is referred to as a winding core 140 when no

distinction is necessary. However, when the first winding core to the third winding core 140(1)-(3) need to be distinguished, they are respectively designated as a winding core 140(1), a winding core 140(2) and a winding core 140(3) as appropriate.

Winding Core 140

FIG. 7 is a cross-sectional view schematically illustrating a winding core 140 disposed at the first position P1. The winding core 140 is a substantially cylindrical member. FIG. 7 shows a winding core 140 viewed in an axial direction, which illustrates a state in which, as shown in FIG. 3, the first separator 31 and the second separator 32 are wound around the winding core 140 disposed at the first position P1. The winding core 140 has the function to retain the separators 31 and 32 that are to be wound on its circumferential surface, as illustrated in FIG. 4. In this embodiment, the winding core 140 includes suction holes 141, a suction passage 142, and a groove 143. The suction holes 141 are holes provided for the purpose of suction-attaching the separators 31 and 32 to be wound on the circumferential surface. The suction passage 142 is a flow passage that is formed inside the winding core 140 and is in communication with the suction holes 141. The suction passage 142 is a flow passage provided for the purpose of providing negative pressure to the suction holes 141. The suction passage 142 may be configured to, for example, be connected to a vacuum line (not shown) that is provided externally, to provide negative pressure. The groove 143 is formed as a receiving portion that receives a blade of the cutter 151 when the separators 31 and 32 are cut. In this embodiment, the groove 143 is formed in the outer circumferential surface of the winding core 140 along the axial direction of the winding core 140. Although the winding core 140 is in a substantially cylindrical shape in this embodiment, it is also possible to use a flat winding core when the winding needs to be in a flat shape. The winding core may be such a winding core that is divided along a radial direction. The winding core divided along a radial direction may be such that the diameter of the winding core is variable.

Cutter 151

The cutter 151 is a cutter that cuts the separators 31 and 32. The cutter 151 is configured so that its blade 151a is pressed against the separators 31 and 32 that are retained on the winding core 140 disposed at the first position P1. In this embodiment, the cutter 151 may be pushed along a guide to a position defined so that the blade 151a can be pressed against the separators 31 and 32 retained on the winding core 140, and may be retracted from that position. Although not shown in the drawings, the cutter 151 is operated so as to be actuated at appropriate timing by an actuator (for example, a cylinder mechanism). The blade 151a may be, for example, a wavy blade (saw blade).

Presser Roller 152

The presser roller 152 is a roller that presses the separators 31 and 32 against the winding core 140 disposed at the first position P1. The separators 31 and 32 are wound while being pressed onto the winding core 140 disposed at the first position P1 by such a presser roller 152. The presser roller 152 functions as a presser jig that presses the separators 31 and 32 against the winding core 140 disposed at the first position P1. In this embodiment, as illustrated in FIG. 7, the presser roller 152 is provided with a plurality of protrusions 152a formed on the outer circumferential surface. In the example shown in FIG. 7, the plurality of protrusions 152a are corrugations. As the roller 152 provided with such protrusions 152a causes the two separators 31 and 32 to be pressed against the winding core 140, the protrusions 152a

serve to intensively apply the force locally, so that the separators **31** and **32** can be pressed strongly. As a result, the separators **31** and **32** are pressed to stick together more suitably. The presser roller **152** may be, for example, in a substantially cylindrical shape, and the circumferential surface thereof may be knurled. The presser roller **152** may be configured to press the separators **31** and **32** onto the winding core **140** disposed at the first position **P1** at an appropriate pressure by means of, for example, a mechanism interiorly equipped with a spring or the like. Also, by means of a guide and an actuator that are not shown in the drawings, the presser roller **152** is moved between a position (see FIG. 3) at which it is pressed onto the separators **31** and **32** that are wound on the winding core **140** disposed at the first position **P1** and a position (see FIG. 5) at which it is detached from the winding core **140**. The presser roller **152** may be composed of a single cylindrical roller provided along a lateral direction of the winding core **140**, or may include a plurality of rollers intermittently disposed along the lateral direction of the winding core **140**.

Stationary Roller **161**, Movable Roller **171**

The stationary roller **161** is provided at a position at which the transfer path **k3** of the first separator **31** and the transfer path **k1** of the positive electrode plate **21** merge. The movable roller **171** is a roller that presses the first separator **31** onto the stationary roller **161** to clamp the first separator **31** therebetween. The movable roller **171** is moved in a predetermined direction by means of a guide and an actuator. The movement of the movable roller **171** is controlled by the controller **200**. The movable roller **171** is configured to be movable between a position at which it presses the first separator **31** against the stationary roller **161** and a position at which it is detached from the stationary roller **161**. The movable roller **171** may be configured to clamp the first separator **31** with a predetermined force by, for example, a spring or the like, when the first separator **31** needs to be clamped. The first separator **31** is clamped by the stationary roller **161** and the movable roller **171** with an appropriate force so that it can be delivered toward the winding core **140** without slack.

Stationary Roller **162**, Movable Roller **172**

The stationary roller **162** is provided at a position at which the transfer path **k4** of the second separator **32** and the transfer path **k2** of the negative electrode plate **22** merge. The movable roller **172** is a roller that presses the second separator **32** onto the stationary roller **162** to clamp the second separator **32** therebetween. The movable roller **172** is moved in a predetermined direction by means of a guide and an actuator. The movement of the movable roller **172** is controlled by the controller **200**. The movable roller **172** is configured to be movable between a position at which it presses the second separator **32** against the stationary roller **162** and a position at which it is detached from the stationary roller **162**. The movable roller **172** may be configured to clamp the second separator **32** with a predetermined force by, for example, a spring or the like, when the second separator **32** needs to be clamped. The second separator **32** is clamped by the stationary roller **162** and the movable roller **172** with an appropriate force so that it can be delivered toward the winding core **140** without slack.

Stationary Roller **163**

The stationary roller **163** is disposed at a predetermined position in the transfer path **k3** of the first separator **31**, and the stationary roller **163** serves to determine the transfer path **k3** of the first separator **31**.

First Chuck **181**

As illustrated in FIG. 3, the first chuck **181** is disposed in front of a pair of rollers **161** and **171** that clamp the first separator **31**, in the transfer path **k1** in which the positive electrode plate **21** is delivered. The first chuck **181** is a member that grips the positive electrode plate **21**. In this embodiment, the first chuck **181** includes a pair of gripping members. Although not shown in the drawings, the first chuck **181** includes a cutter that cuts the positive electrode plate **21**. Although not shown in the drawings, the first chuck **181** is operated at appropriate timing by a guide and an actuator (for example, a cylinder mechanism). The operation of the first chuck **181** is configured to be controlled by the controller **200**.

In the state shown in FIG. 3, the first separator **31** is retained by the winding core **140** disposed at the first position **P1** and is sandwiched by the pair of rollers **161** and **171**, to extend along the transfer path **k3**. The first chuck **181** grips the positive electrode plate **21** in front of the pair of rollers **161** and **171**. When the positive electrode plate **21** is taken up on the winding core **140** disposed at the first position **P1**, the first chuck **181** inserts the retained positive electrode plate **21** into the gap between the pair of rollers **161** and **171**, and releases the positive electrode plate **21**, as illustrated in FIG. 4. Thereby, the positive electrode plate **21**, together with the first separator **31**, is pulled between the pair of rollers **161** and **171** and is taken up on the winding core **140** disposed at the first position **P1**. When the positive electrode plate **21** is delivered by a predetermined length, the winding core **140** stops the take-up operation. The positive electrode plate **21** is gripped by the first chuck **181** and is cut between the first chuck **181** and the pair of rollers **161** and **171**. The first chuck **181** is configured to move appropriately between a predetermined position at which it grips the positive electrode plate **21** and a predetermined position at which it inserts the positive electrode plate **21** into the gap between the pair of rollers **161** and **171**.

Second Chuck **182**

As illustrated in FIG. 3, the second chuck **182** is disposed in front of a pair of rollers **162** and **172** that clamp the second separator **32**, in the transfer path **k2** in which the negative electrode plate **22** is delivered. The second chuck **182** is a member that grips the negative electrode plate **22**. In this embodiment, the second chuck **182** includes a pair of gripping members. Although not shown in the drawings, the second chuck **182** includes a cutter that cuts the negative electrode plate **22**. Although not shown in the drawings, the second chuck **182** is operated at appropriate timing by a guide and an actuator (for example, a cylinder mechanism). The operation of the second chuck **182** is configured to be controlled by the controller **200**.

In the state shown in FIG. 3, the second separator **32** is retained by the winding core **140** disposed at the first position **P1** and is sandwiched by the pair of rollers **162** and **172**, to extend along the transfer path **k4**. The second chuck **182** grips the negative electrode plate **22** in front of the pair of rollers **162** and **172**. When the negative electrode plate **22** is taken up on the winding core **140** disposed at the first position **P1**, the second chuck **182** inserts the retained negative electrode plate **22** into the gap between the pair of rollers **162** and **172**, and releases the negative electrode plate **22**, as illustrated in FIG. 4. Thereby, the negative electrode plate **22**, together with the second separator **32**, is pulled between the pair of rollers **162** and **172** and is taken up on the winding core **140** disposed at the first position **P1**. As mentioned previously, when the positive electrode plate **21** is delivered by a predetermined length, the winding core **140** stops the take-up operation. In other words, when the

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negative electrode plate 22 is delivered by a predetermined length, the winding core 140 stops the take-up operation. The negative electrode plate 22 is gripped by the second chuck 182 and is cut between the second chuck 182 and the pair of rollers 162 and 172. The second chuck 182 is configured to move appropriately between a predetermined position at which it grips the negative electrode plate 22 and a predetermined position at which it inserts the negative electrode plate 22 into the gap between the pair of rollers 162 and 172.

The positive electrode plate 21 and the negative electrode plate 22 may be inserted respectively between the pair of rollers 161 and 171 and between the pair of rollers 162 and 172, for example, after the first separator 31 and the second separator 32 are wound approximately one time around the outer circumferential surface of the winding core 140.

Movable Roller 173

As illustrated in FIG. 6, the movable roller 173 is a roller that presses the first separator 31 and the second separator 32 against the winding core 140 disposed at the first position P1 when the first separator 31 and the second separator 32 are cut. The movable roller 173 is moved in a predetermined direction by means of a guide and an actuator. The movement of the movable roller 173 is controlled by the controller 200. As illustrated in FIG. 6, when the first separator 31 and the second separator 32 are cut, the movable roller 173 is disposed at a position at which the movable roller 173 presses the first separator 31 and the second separator 32 against the winding core 140 disposed at the first position P1. At other times, the movable roller 173 moves to, as illustrated in FIG. 3, a position that is detached from the winding core 140 disposed at the first position P1. The movable roller 173 may be configured to clamp the first separator 31 with a predetermined force by, for example, a spring or the like, when it presses the first separator 31 and the second separator 32 against the winding core 140.

As illustrated in FIG. 6, the cutter 151 is pressed against the winding core 140 disposed at the first position P1 so that the first separator 31 and the second separator 32 can be cut. In this embodiment, as illustrated in FIG. 7, the groove 143 is formed in the outer circumferential surface of the winding core 140. When the cutter 151 is pressed against the winding core 140, the groove 143 formed in the outer circumferential surface of the winding core 140 is disposed to face the position where the cutter 151 is pressed. With the groove 143 disposed so as to face the cutter 151, the first separator 31 and the second separator 32 are pressed against the winding core 140. This allows the first separator 31 and the second separator 32 to be attached to the winding core 140. Further, in this state, the cutter 151 is pressed against the first separator 31 and the second separator 32 that is retained on the winding core 140. As a result, the first separator 31 and the second separator 32 are cut. Because the blade of the cutter 151 goes into the groove 143 of the winding core 140, the first separator 31 and the second separator 32 can be cut more reliably and more cleanly. Moreover, the winding core 140 is unlikely to be damaged, and contaminants are unlikely to form.

Movable Roller 174

The movable roller 174 is a roller that applies tension to the first separator 31 and the second separator 32, as illustrated in FIG. 6, when the first separator 31 and the second separator 32 are cut. The movable roller 174 is moved in a predetermined direction by means of a guide and an actuator. The movement of the movable roller 174 is controlled by the controller 200.

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For example, as illustrated in FIG. 4, the positive electrode plate 21, the first separator 31, the negative electrode plate 22, and the second separator 32 are stacked respectively and wound up by the winding core 140(1) disposed at the first position P1. The winding core 140(1), which has taken up the positive electrode plate 21, the first separator 31, the negative electrode plate 22, and the second separator 32, moves from the first position P1 to the second position P2, as illustrated in FIG. 5. At that time, another winding core 140(2) moves to the first position P1. Then, as illustrated in FIG. 6, the first separator 31 and the second separator 32 are suction-attached to the winding core 140(2), which is newly disposed at the first position P1, so that the first separator 31 and the second separator 32 are retained on the outer circumferential surface of the winding core 140(2). At this time, the first separator 31 and the second separator 32 that have been wound up on the winding core 140(1) disposed at the second position P2 are retained in a continuous condition on the outer circumferential surface of the winding core 140(2) disposed at the first position P1.

When the winding core 140(1) moves from the first position P1 to the second position P2, the movable roller 174 is pushed toward the first separator 31 and the second separator 32 at appropriate timing, so as to be pressed onto the first separator 31 and the second separator 32, as illustrated in FIG. 6. By the movable roller 174, the first separator 31 and the second separator 32 are delivered without causing slack when the winding core 140(1) moves from the first position P1 to the second position P2. Other than this timing, the movable roller 174 is retracted to a position away from the turret 120, as illustrated in FIGS. 3 to 5.

Index Unit 185

The index unit 185 is provided at a central portion of the turret 120. On the turret 120, the three winding cores 140(1)-(3) are distributed uniformly along the circumferential direction, as described previously. The index unit 185 includes a substantially equilateral triangular shaped base that rotates together with the turret 120. At the apexes of the base, respective index rollers 186 to 188 are disposed, and the index rollers 186 to 188 are disposed respectively between the three winding cores 140(1)-(3).

The index unit 185 is constructed as follows. When the winding core 140(1) on which the positive electrode plate 21, the first separator 31, the negative electrode plate 22, and the second separator 32 are wound is moved from the first position P1 to the second position P2, one of the index rollers 186 to 188 that is placed from the first position P1 to the second position P2, namely the index roller 186, is pressed against the first separator 31 and the second separator 32 from radially inside. Such an index roller 186 and the movable roller 174 allow the first separator 31 and the second separator 32 to be delivered between the first position P1 and the second position P2 without causing slack. At the time shown in FIG. 6, the index roller 186 presses the first separator 31 and the second separator 32 from radially inside, and the index unit 185 rotates with rotation of the turret 120. Thus, the index rollers 186 to 188 of the index unit 185 each sequentially function, one by one, as a roller that presses the first separator 31 and the second separator 32 from radially inside when the winding core 140 around which the positive electrode plate 21, the first separator 31, the negative electrode plate 22, and the second separator 32 have been wound is moving from the first position P1 to the second position P2.

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Winding Termination Device 190

As illustrated in FIG. 6, for example, the winding core 140(1), which has rolled up the positive electrode plate 21, the first separator 31, the negative electrode plate 22, and the second separator 32, moves to the second position P2, which is away from the first position P1. Then, after the separators 31 and 32 are cut, the cut portions of the separators 31 and 32 are rolled up to the cut edge portions. The winding termination device 190 is disposed at the second position P2. The winding termination device 190 includes a presser roller 191 and a tape attaching device 192. When the winding core 140 that has moved to the second position P2 rolls up the cut portions of the positive electrode plate 21, the first separator 31, the negative electrode plate 22, and the second separator 32 to the cut edge portions, the presser roller 191 is pressed against an outermost circumference portion of the second separator 32 that is wound around the winding core 140(1). As a result, the cut portions of the positive electrode plate 21, the first separator 31, the negative electrode plate 22, and the second separator 32 can be wound up without causing slack. The tape attaching device 192 is a device that attaches a tape for fixing the cut edge portion of the outermost circumference of the second separator 32 or the first separator 31. Such a winding termination process may be performed, for example, in parallel with the process of winding the first separator 31, the positive electrode plate 21, and the second separator 32, and the negative electrode plate 22 around the winding core 140(2) that is newly disposed at the first position P1.

Furthermore, in this embodiment, as illustrated in FIG. 6, for example, the winding machine 100 performs the winding termination process and newly winds up the positive electrode plate 21, the first separator 31, the negative electrode plate 22, and the second separator 32 on the winding core 140(2) disposed at the first position P1. Thereafter, the winding machine 100 allows the turret 120 to rotate. The winding core 140(1), for which the winding termination process has been performed, is moved to the third position P3, the winding core 140(2) is moved to the second position P2, and further another winding core 140(3) is disposed at the first position P1. At this time, the first separator 31 and the second separator 32 that have been wound up on the winding core 140(2) disposed at the second position P2 are retained in a continuous condition on the outer circumferential surface of the winding core 140(3) disposed at the first position P1. Then, after the separators 31 and 32 are cut, the winding termination process for the winding core 140(2) is performed at the second position P2. At the first position P1, the positive electrode plate 21, the first separator 31, the negative electrode plate 22, and the second separator 32 are newly wound around the winding core 140(3). At the third position P3, a wound stack 20a is removed from the winding core 140(1) (see FIG. 3). After removed from the winding core 140(1), the wound stack 20a is pressed into a flat shape, which can be handled as a wound electrode assembly 20. Thus, the winding cores 140(1)-(3) provided on the turret 120 move from the first position P1 to the third position P3 sequentially. The positive electrode plate 21, the first separator 31, the negative electrode plate 22, and the second separator 32 are continuously wound around the winding cores 140(1)-(3) one after another.

The present inventors discovered that, in manufacturing batteries 2 using the winding machine 100 as described above, there is still room for improvement in suction-attaching of separators 31 and 32 to the winding core 140 and cutting of separators 31 and 32. The present inventors

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believe that the use of a winding core 140 as described in the following is desirably able to improve production efficiency.

FIG. 8 is a cross-sectional view of a winding core 140. FIG. 9 is a schematic view illustrating the outer circumferential surface of the winding core 140. FIG. 9 shows a view in which the winding core 140 is virtually unrolled along the circumferential direction so that the entire outer circumferential surface of the winding core 140 can be shown in a plane. In this embodiment, the winding core 140 includes a first component 140a and a second component 140b, as illustrated in FIG. 8. The first component 140a and the second component 140b includes respective outer circumferential surfaces 140a1 and 140b1 onto which the separators 31 and 32 are to be wound. The first component 140a has such a shape that two substantially semi-cylindrical shaped members having different diameters are connected so as to cause their inner circumferential surfaces to face each other. The second component 140b has a substantially semi-cylindrical shape.

The first component 140a includes a flat surface 140a2 and a protruding surface 140a3 in its surface that faces the second component 140b. The flat surface 140a2 is formed at both opposite lateral ends of the surface of the first component 140a that faces the second component 140b. The protruding surface 140a3 protrudes from the flat surface 140a2 toward the second component 140b. The protruding surface 140a3 is formed along the axial direction of the winding core 140 and is in a substantially semi-cylindrical shape.

The second component 140b includes a flat surface 140b2 and an inner circumferential surface 140b3 in its surface that faces the first component 140a. The flat surface 140b2 faces the flat surface 140a2 of the first component 140a. The flat surfaces 140a2 and 140b2 are parallel to each other. The radius of the inner circumferential surface 140b3 is greater than the outer diameter of the protruding surface 140a3 of the first component 140a so that the protruding surface 140a3 can fit within the inner circumferential surface 140b3.

A clearance gap 140c is provided between the first component 140a and the second component 140b. Specifically, the clearance gap 140c is provided between the flat surfaces 140a2 and 140b2 and between the protruding surface 140a3 and the inner circumferential surface 140b3. The first component 140a and the second component 140b, which forms the winding core 140, are configured to be openable and closable. FIG. 8 shows the winding core 140 that is in an open state, in which the separators 31 and 32 (see FIG. 7) are wound on the outer circumferential surfaces 140a1 and 140b1. In a closed state, the clearance gap between the flat surfaces 140a2 and 140b2 is narrower. In this embodiment, the flat surfaces 140a2 and 140b2 are configured to come into contact with each other when the winding core 140 is in the closed state. The opening and closing mechanism for the first component 140a and the second component 140b is not limited to a particular mechanism. For example, the opening and closing of the first component 140a and the second component 140b may be effected by a cylinder mechanism or the like.

The winding core 140 includes a plurality of suction holes 141 for suction-attaching the first separator 31. The suction holes 141 are holes provided for the purpose of suction-attaching the separators 31 and 32 that are to be wound on the outer circumferential surface. As illustrated in FIG. 9, the suction holes 141 are formed at a predetermined pitch along the axial direction and the circumferential direction of the winding core 140. From the viewpoint of causing the separators 31 and 32 to be suction-attached to the winding

core **140**, it is desirable that the suction holes **141** be provided in a plurality of rows along the axial direction of the winding core **140**. The shape of the suction holes **141** may be, but is not particularly limited to, a circular shape or a polygonal shape, for example. From the viewpoint of ease of processing, the shape of the suction holes **141** may preferably be a circular shape.

The size and pitch of the plurality of suction holes **141** are not particularly limited. The suction holes **141** may preferably be provided at, for example, a less than or equal to 10 mm, more preferably at a pitch of less than or equal to 5 mm. The total area of aperture of the suction holes **141** may preferably be, for example, about 200 mm² to about 300 mm², more preferably about 250 mm² to about 280 mm². When the area of the region of the winding core **140** that is in contact with the first separator **31** is A and the total area of aperture of the suction holes **141** is B, the ratio B/A may preferably be less than or equal to 5%, more preferably less than or equal to 1%.

As illustrated in FIG. 8, the winding core **140** includes a flow passage **142** that communicates with the suction holes **141**. The flow passage **142** is formed inside the winding core **140**. When the inside of the flow passage **142** is brought to a negative pressure, the separators **31** and **32** can be suction-attached to the winding core **140** through the suction holes **141**. The flow passage **142** may be configured to, for example, be connected to a vacuum line (not shown) that is provided externally, to provide negative pressure. In this embodiment, the suction holes **141** and the flow passage **142** are provided in the first component **140a**. The flow passage **142** is formed inside of the first component **140a** and the protruding surface **140a3** that are in substantially semi-cylindrical shapes having different inner diameters.

The flow passage **142** may be configured to be able to cause the pressure of the inside of the flow passage **142** to be a positive pressure. For example, the flow passage **142** may be connected externally to an air supply line (not shown) that is switchable to a vacuum line. By causing the inside of the flow passage **142** to be a positive pressure, the separators **31** and **32** can be detached from the outer circumferential surface of the winding core **140**. By switching the pressure of the inside of the flow passage **142** between a negative pressure and a positive pressure, the separators **31** and **32** can be easily suction-attached to and detached from the outer circumferential surfaces **140a1** and **140b1** of the winding core **140**.

Although this embodiment shows that only one flow passage **142** is provided, this is merely an example, and it is also possible that a plurality of flow passages may be formed inside the winding core **140**. It is also possible that the plurality of flow passages may be connected to respective different vacuum lines and may communicate with a plurality of different suction holes (suction hole groups). As a result, it is possible to control the timing of suction-attaching for each of the suction hole groups. Even when there is a suction hole group to which the separators **31** and **32** are not suction-attached, this configuration can prevent reduction of the suction force of other suction hole groups to which the separators **31** and **32** are suction-attached.

The plurality of flow passages may be divided into two groups, the flow passage(s) connected to the vacuum line for suction-attaching the separators **31** and **32** and the flow passage(s) connected to the air supply line for detaching the separators **31** and **32**. Moreover, an atmosphere relief valve (not shown) may be provided outside the flow passage **142** so that the flow passage **142** can be opened to the atmospheric pressure.

In this embodiment, the winding core **140** is divided into two parts, the first component **140a** and the second component **140b**, as described above. The suction holes **141**, the flow passage **142**, and the groove **143** are provided in the first component **140a**. The separators **31** and **32** are suction-attached to the first component **140a** only.

The winding core **140** includes a groove **143**. The groove **143** is formed as a receiving portion that receives a blade of the cutter **151** (see FIG. 7) when the separators **31** and **32** are cut. The groove **143** is formed in the outer circumferential surface of the winding core **140** along the axial direction of the winding core **140**.

As illustrated in FIG. 9, greater than or equal to 80% by aperture area ratio of the suction holes **141** are formed in a first region (R1) of the winding core **140**, wherein the first region (R1) is defined by dividing an outer circumferential surface of the winding core **140** into four equal parts that are respectively first to fourth regions (R1-R4) starting from a position of the winding core **140** (i.e., the groove **143**) that faces a starting end of winding of the first separator **31** of the wound electrode assembly that has been cut. In other words, the total of the aperture area of the suction holes **141** provided in the winding core **140** is 100%, the total of the aperture area of the suction holes **141** provided in the first region R1 of the winding core **140** is greater than or equal to 80%. In the present description, a region of the outer circumference of the winding core **140** starting from the groove **143** and extending to 90 degrees in a direction (also referred to as a winding direction) in which the separators **31** and **32** are wound is referred to as a first region R1. Likewise, a region extending from the terminal end of the first region R1 to 90 degrees in the winding direction is referred to as a second region R2, a region extending from the terminal end of the second region R2 to 90 degrees in the winding direction is referred to as a third region R3, and a region extending from the terminal end of the third region R3 to 90 degrees in the winding direction is referred to as a fourth region R4. The first region R1 is a region in which the cut separators **31** and **32** are started to wind.

It is possible that greater than or equal to 90%, or more preferably greater than or equal to 95%, by aperture area ratio, of the suction holes **141** may be formed in the first region R1. It is most desirable that 100% of the suction holes **141** be formed in the first region R1. Moreover, when the first region R1 is circumferentially divided into two equal parts and one that is closer to the groove **143** is defined as a first sub-region R11 and the other one that is farther from the groove **143** is defined as a second sub-region R12, greater than or equal to 70%, by aperture area ratio, of the suction holes **141** may preferably be formed in the first sub-region R11. In this way, substantially all the suction holes **141** may preferably be disposed in a region close to the starting end of winding of the separators **31** and **32** (i.e., in a region close to the portion at which the separators **31** and **32** are cut). This is merely an example, and the suction holes **141** may be formed in an area other than the first region R1. In addition, in this embodiment, the width W of the suction hole formation region, in which the plurality of suction holes **141** are formed, is less than the width of the first separator **31**. In other words, the first separator **31** has a width such that it can cover all of the suction holes **141** along the axial direction of the winding core **140**.

The size of the winding core **140** is not particularly limited. However, the radius of the winding core **140** may preferably be greater than or equal to 30 mm, more preferably greater than or equal to 40 mm, so that a large-sized wound electrode assembly can be easily manufactured.

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When the winding core is in a flat shape, it is preferable that the major axis length be greater than or equal to 30 mm, more preferably 40 mm.

In association with the method of manufacturing a battery 2 including a wound electrode assembly 20 in which a first separator 31, a negative electrode plate 22, a second separator 32, and a positive electrode plate 21 are wound together, the winding machine 100 including the winding core 140 as described above embodies the following steps (A) to (C).

Step (A): suction-attaching the first separator 31 to the winding core 140.

Step (B): winding the first separator 31 onto the winding core 140.

Step (C): cutting the first separator 31 and the second separator 32.

In step (A), the first separator 31 is suction-attached to the winding core 140 that is disposed at the first position P1. As described previously, each of the separators 31 and 32 is a porous resin sheet. This means that suction through the suction holes 141 is also effected on the second separator 32 through the pores in the first separator 31. As a result, the second separator 31 is suction-attached onto the first separator 31. Thus, the first separator 31 and the second separator 32 are suction-attached to the winding core 140 in a stacked condition.

In step (B), the first separator 31 is wound onto the winding core 140 together with the second separator 32. In this embodiment, the first separator 31 and the second separator 32 are wound approximately one time around the winding core 140.

Thereafter, as illustrated in FIG. 4, the positive electrode plate 21 and the negative electrode plate 22 are delivered from the transfer path k1 and the transfer path k2. Subsequently, the second separator 32, the negative electrode plate 22, the first separator 31, and the positive electrode plate 21 are stacked on top of each other and wound together.

Step (C) involves cutting the first separator 31 and the second separator 32 wound on the winding core 140(1) that is moved away from the first position P1 in step (B) at a location on or near the other winding core 140(2) disposed at the first position P1 in step (B), with the first separator 31 and the second separator 32 being stacked and retained on an outer circumferential surface of the other winding core 140(2) disposed at the first position P1 in step (B) (see FIG. 6).

The above-described method of manufacturing a battery 2 uses a winding core 140 including a plurality of suction holes 141 as the winding core onto which the separators 31 and 32 (see FIG. 7) are to be suction-attached, as illustrated in FIG. 9. In the winding core 140, greater than or equal to 80%, by aperture area ratio, of the suction holes 141 are formed in the first region R1. The first region R1 is a region that is opposite to a portion at which the first separator 31 starts to be wound. Because the suction holes 141 are intensively disposed at a portion at which the first separator 31 starts to be wound, most of the suction holes 141 are covered by the first separator 31 even at the initial stage of winding. As a result, air is unlikely to leak from the suction holes 141, so the suction force can be prevented from decreasing and production efficiency can be improved.

From these viewpoints, it is possible that, when being cut in step (C), the length of the first separator 31 and the second separator 32 circumferentially wound on the winding core 140 disposed at the first position P1 may be set at, for example, a length that allows the first separator 31 and the second separator 32 to be stably wound around the winding

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core 140. For example, according to the knowledge of the present inventors, as illustrated in FIG. 6, the first separator 31 and the second separator 32 may be cut with the first separator 31 and the second separator 32 being wound on a circumferential region of 15 degrees to 180 degrees of another winding core [the second winding core 140(2)] that is different from the winding core [the first winding core 140(1)] onto which the first separator 31 is wound in step (B). From the viewpoint of stable winding, the first separator 31 and the second separator 32 may be wound on the winding core 140 with a sufficient length. Preferably, the first separator 31 and the second separator 32 may be cut with the first separator 31 and the second separator 32 being wound on a circumferential region of greater than or equal to 30 degrees of the winding core 140(2). Furthermore, from the viewpoint of handleability, the first separator 31 and the second separator 32 may be cut with the first separator 31 and the second separator 32 being wound on a region of greater than or equal to 30 degrees, more preferably greater than or equal to 45 degrees of the winding core 140. The first separator 31 and the second separator 32 may be cut with the first separator 31 and the second separator 32 being wound on a region of less than or equal to 150 degrees, more preferably less than or equal to 120 degrees of the winding core 140. Here, the angles may be specified by an angle about the winding center of the winding core that is viewed in the axial direction from the far end of the winding core 140. The term "region" means an arc portion of the sector shape centered on the winding center, which is on the outer circumferential surface of the winding core 140. When the just-mentioned region contains the groove 143, the region on which the first separator 31 and the second separator 32 are wound may be provided in a portion of the outer circumferential surface of the winding core 140 that excludes the Thus, the length of the first separator 31 and the second separator 32 circumferentially wound on the winding core 140(2) may be set appropriately when the first separator 31 and the second separator 32 are cut in step (C). This enables the winding on the winding core 140(2) disposed at the first position P1 in step (B) to start in a stable condition. Note that the groove 143 of the winding core 140 may be disposed in the region of the winding core 140 on which the first separator 31 and the second separator 32 are wound. In this case, in the region of the winding core 140 on which the first separator 31 and the second separator 32 are wound, there may be a portion in which the first separator 31 or the second separator 32 is not in contact with the winding core 140. Also, the wider the width of the first separator 31 and the second separator 32 is, the greater the contact area with the winding core 140. This enables the first separator 31 and the second separator 32 to be wound more stably. From such a viewpoint, the width of the first separator 31 and the second separator 32 may be, for example, greater than or equal to 20 cm, more preferably greater than or equal to 25 cm.

In step (C), the first separator 31 may be cut, with the first separator 31 being in contact with another winding core [the second winding core 140(2)] that is different from the winding core [the first winding core 140(1)] onto which the first separator 31 is wound in step (B) on an upstream side and a downstream side of a cut position at which the first separator 31 is cut in the transfer path k3 of the first separator 31. As a result, the first separator 31 can be cut in a stable manner. Moreover, also when the first separator 31 is wound on the second winding core 140(2), the position at which the winding is started can be stabilized.

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Note that, as illustrated in FIG. 7, the upstream side of the separator **31** may preferably be pressed by a jig such as a presser roller **152** when cutting. The downstream side may preferably be suction-attached through the suction holes **141** or the like. The downstream side may be pressed with a roller or the like in addition to the suction-attaching through the suction holes **141**. This allows cutting of the first separator **31** to be made in a more stable manner.

In step (C), when cutting the first separator **31** and the second separator **32**, the first separator **31** and the second separator **32** may be pressed onto another winding core [the second winding core **140(2)**] that is different from the winding core [the first winding core **140(1)**] onto which the first separator **31** is wound in step (B), by a presser jig (the presser roller **152** in the embodiment shown in FIG. 3). As a result, the first separator **31** and the second separator **32** are retained on the winding core **140** more stably. Moreover, when the first separator **31** is suction-attached to the winding core **140** as well, the first separator **31** can be suction-attached in a more stable condition. In this case, the presser jig may be a roller including a plurality of protrusions **152a** formed on the outer circumferential surface, such as the presser roller **152** as described above. The roller including a plurality of protrusions **152a** formed on the outer circumferential surface enables the first separator **31** and the second separator **32** to be pressed onto the winding core **140** by the plurality of protrusions **152a**. Therefore, the first separator **31** can be suction-attached to the winding core **140** in a more stable condition.

In the above-described embodiment, another winding core [the second winding core **140(2)** in FIG. 3] that is different from the winding core [the first winding core **140(1)** in FIG. 3] on which the first separator **31** is wound in step (B) includes a groove **143** formed along the axial direction at a position thereof at which the first separator **31** and the second separator **32** are cut. Because the groove **143** serves as a receiving portion that receives the blade of the cutter **151**, the separators **31** and **32** can be cut in a stable manner. Moreover, because the winding core **140** is not hit by the blade of the cutter **151**, damages to the winding core **140** are reduced.

It should be noted that the groove **143** may preferably be close in distance to the suction holes **141**. Although not limited to these distances, the distance between the groove **143** and the suction holes **141** may preferably be less than or equal to 20 mm, more preferably less than or equal to 10 mm, and still more preferably less than or equal to 5 mm. When the groove **143** and the suction holes **141** are located in close proximity, the portions near the cut edges of the separators **31** and **32** are retained by means of the suction holes **141**. This allows the separators **31** and **32** to be less likely to be bent in a region extending from the cut edge portion to the portion that is sucked through the suction holes **141**.

In step (C), the first separator **31** and the second separator **32** may be cut by a blade that is movable toward another winding core [second winding core **140(2)**] that is different from the winding core [first winding core **140(1)**] on which the first separator **31** is wound in step (B). Such cutting makes it possible to stably cut the first separator **31** and the second separator **32**. Here, such cutting may be carried out at room temperature. It is also possible that the first separator **31** and the second separator **32** may be thermally cut by heating the blade **151a**.

As illustrated in FIG. 8, the winding core **140** may be configured to be divided into at least two parts in a radial direction of the winding core **140**, and the separators **31** and

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32 may be configured to be suction-attached to a portion of the divided parts of the winding core only. In the above-described embodiment, the winding core **140** includes a first component **140a** and a second component **140b**, and is configured to be openable and closable. Such a configuration allows the winding core **140** to be operated so that the diameter of the winding core **140** can be made smaller when removing the wound stack **20a** (see FIG. 6) after winding. As a result, it is easy to remove the wound stack **20a**.

In the above-described embodiment, the width W (see FIG. 9) of the suction hole formation region, in which the plurality of suction holes **141** are formed, is less than the width of the first separator **31**. Because the suction hole formation region has such a width, the first separator **31** is able to cover the entirety of the suction holes **141** across the width of the first separator **31** (i.e., along the axial direction of the winding core **140**). This prevents air from leaking from some of the suction holes **141**. As a result, it is possible to prevent a reduction of the suction force for suction-attaching the separators **31** and **32**.

Various embodiments of the invention have been described hereinabove according to the present disclosure. Unless specifically stated otherwise, the embodiments described herein do not limit the scope of the present invention. It should be noted that various other modifications and alterations may be possible in the embodiments of the invention disclosed herein. In addition, the features, structures, or steps described herein may be omitted as appropriate, or may be combined in any suitable combinations, unless specifically stated otherwise.

What is claimed is:

1. A method of manufacturing a battery including a wound electrode assembly wherein a first separator, a negative electrode plate, a second separator, and a positive electrode plate are wound together, the method comprising the steps of:

(A) suction-attaching the first separator to a winding core; and

(B) winding the first separator onto the winding core, wherein:

the winding core includes a plurality of suction holes for suction-attaching the first separator; and

greater than or equal to 80% by aperture area ratio of the suction holes are formed in a first region of the winding core, wherein the first region is defined by dividing an outer circumferential surface of the winding core into four equal parts, the four equal parts respectively being first to fourth regions starting from a position of the winding core that faces a starting end of winding of the first separator of the wound electrode assembly.

2. The method according to claim 1, further comprising step (C) of cutting the first separator and the second separator.

3. The method according to claim 2, wherein in step (C), the first separator and the second separator are cut with the first separator and the second separator being wound on a circumferential region of 15 degrees to 180 degrees of another winding core that is different from the winding core onto which the first separator is wound in step (B).

4. The method according to claim 2, wherein in step (C), the first separator is cut, with the first separator being in contact with the other winding core that is different from the winding core onto which the first separator is wound in step (B) in an upstream side and a downstream side of a cut position at which the first separator is cut in a transfer path of the first separator.

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5. The method according to claim 2, wherein in step (C), when cutting the first separator and the second separator, the first separator and the second separator are pressed against the other winding core by a presser jig, the other winding core being different from the winding core onto which the first separator and the second separator are wound in step (B).

6. The method according to claim 5, wherein the presser jig comprises a roller including a plurality of protrusions formed on its surface.

7. The method according to claim 2, wherein in step (C), a groove extending along an axial direction of the other winding core is formed in the other winding core that is different from the winding core onto which the first separator is wound in step (B), the groove formed at a position of the other winding core at which the first separator and the second separator are to be cut.

8. The method according to claim 2, wherein in step (C), the first separator and the second separator are cut by a blade

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that is movable toward the other winding core that is different from the winding core onto which the first separator is wound in step (B).

9. The method according to claim 2, wherein the winding core is divided into at least two parts in a radial direction of the winding core, and the first separator is suction-attached to a portion of the divided parts of the winding core only.

10. The method according to claim 2, wherein a suction hole formation region in which the plurality of suction holes are formed has a width less than a width of the first separator.

11. The method according to claim 1, wherein the winding core is divided into at least two parts in a radial direction of the winding core, and the first separator is suction-attached to a portion of the divided parts of the winding core only.

12. The method according to claim 1, wherein a suction hole formation region in which the plurality of suction holes are formed has a width less than a width of the first separator.

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