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Bus Bar Connection Structure

Abstract

A busbar coupling structure includes a first busbar and a second busbar. The first busbar includes a first body portion extending in a front-rear direction, and has a recessed portion that is recessed in the front-rear direction at one end portion of the first body portion in the front-rear direction. The second busbar includes a second body portion extending in an oblique direction relative to the front-rear direction, and has a protruding portion that protrudes in the oblique direction from one end portion of the second body portion in the oblique direction. The recessed portion and the protruding portion have such shapes that allow the second busbar to rotate relatively to the first busbar around the protruding portion as an axis in a plane that includes the front-rear direction and the oblique direction. The recessed portion and the protruding portion are joined to each other.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This is a continuation of International Application No. PCT/JP2023/040659 filed on Nov. 10, 2023, and claims priority from Japanese Patent Application No. 2022-197910 filed on Dec. 12, 2022, the entire content of which is incorporated herein by reference.

TECHNICAL FIELD
[0002] The present invention relates to a busbar coupling structure.
BACKGROUND ART
[0003] In a battery pack mounted on an electric automobile or a hybrid automobile that travels using an electric motor, a busbar is used for connecting electrodes of a plurality of cells (for example, see Patent Literature 1).
[0004] As an example of wiring a busbar, which is a flat rectangular metal conductor, in an oblique direction, in a busbar coupling structure **101** shown in FIG. **7**, a busbar **112** having an inclined end face in accordance with a wiring direction is disposed between linearly extending busbars **110** and **113**, and the busbars are joined together. In addition, as another example, in a busbar coupling structure **101**A shown in FIG. **8**, an upper face of a busbar **122** disposed in accordance with a wiring direction is joined to lower faces of busbars **121** and **123** extending linearly.
CITATION LIST
Patent Literature
[0005] Patent Literature 1: JP2017-4744A
SUMMARY OF INVENTION
[0006] However, in the busbar coupling structure **101** shown in FIG. **7**, since a joint angle is different for each wiring direction and an inclination angle of the end face of the busbar **112** needs to be different, versatility is low. Further, in the busbar coupling structure **101**A shown in FIG. **8**, since the busbars are joined to each other on the upper and lower faces, a space in a thickness (plate thickness) direction is required. Further, in the busbar coupling structure described in Patent Literature 1, since the busbars are connected to each other via a hinge portion and the hinge portion has a cylindrical portion formed by bending an end portion of each busbar into a cylindrical shape, a space of the cylindrical portion is required in addition to a plate thickness of the busbars.
[0007] The present invention has been made in view of the above-described circumstances, and an object thereof is to provide a busbar coupling structure that can improve versatility and save space.
[0008] In order to achieve the object described above, the busbar coupling structure according to the present invention is characterized as follows.
[0009] A busbar coupling structure including: [0010] a first busbar having a first body portion extending in a first direction, and a recessed portion that is recessed in the first direction at one end portion of the first body portion in the first direction; and [0011] a second busbar having a second body portion extending in a second direction, and a protruding portion that protrudes in the second direction from one end portion of the second body portion in the second direction, in which [0012]

the recessed portion and the protruding portion have such shapes that allow the second busbar to rotate relatively to the first busbar around the protruding portion as an axis in a plane that includes the first direction and the second direction, and [0013] the recessed portion and the protruding portion are jointed to each other.
[0014] According to the present invention, it is possible to provide a busbar coupling structure that can improve versatility and save space.
[0015] The present invention has been briefly described above. Further, the details of the present invention can be clarified by reading a mode (hereinafter, referred to as an “embodiment”) for carrying out the invention to be described below with reference to the accompanying drawings.

Description

BRIEF DESCRIPTION OF DRAWINGS
[0016] FIG. **1** is a perspective view showing a busbar coupling structure according to a first embodiment;
[0017] FIG. **2** is an exploded perspective view of the busbar coupling structure shown in FIG. **1**;
[0018] FIG. **3** is an enlarged top view of a part of the busbar coupling structure shown in FIG. **1**;
[0019] FIG. **4** is a perspective view showing a busbar coupling structure according to a second embodiment;
[0020] FIG. **5** is an exploded perspective view of the busbar coupling structure shown in FIG. **4**;
[0021] FIG. **6** is an enlarged top view of a part of the busbar coupling structure shown in FIG. **4**;
[0022] FIG. **7** is a perspective view showing an example of a busbar coupling structure in the related art; and
[0023] FIG. **8** is a perspective view showing another example of a busbar coupling structure in the related art.
DESCRIPTION OF EMBODIMENTS
[0024] Specific embodiments of the present invention will be described below with reference to the drawings.
First Embodiment
[0025] FIG. **1** is a perspective view showing a busbar coupling structure **1** according to a first embodiment. FIG. **2** is an exploded perspective view of the busbar coupling structure **1** shown in FIG. **1**. FIG. **3** is an enlarged top view of a part of the busbar coupling structure **1** shown in FIG. **1**. Hereinafter, for convenience of description, as shown in FIG. **1**, a “front-rear direction”, a “left-right direction”, and an “upper-lower direction” are defined. The “front-rear direction”, the “left-right direction”, and the “upper-lower direction” are orthogonal to one another. The front-rear direction is an example of a first direction.
[0026] The busbar coupling structure **1** is to be assembled between components and/or devices of an automobile and used for electrical connections within a battery pack that is used as a power supply to drive a motor of a vehicle, for example. The busbar coupling structure **1** is a busbar for supplying vehicle driving power, that is, a high-voltage busbar.
[0027] The busbar coupling structure **1** includes a busbar **11**, a busbar **13**, a busbar **15**, a busbar **17**, and a busbar **19**. As described below, adjacent busbars are joined together by, for example, laser welding. The busbar **15** is an example of a first busbar, and the busbar **17** is an example of a second busbar.
[0028] Each of the busbars **11**, **13**, **15**, and **17** is formed by punching a conductive metal plate having a predetermined thickness, and has a flat rectangular parallelepiped shape. The busbars **11**, **15**, and **19** extend in the front-rear direction. The busbar **13** extends in the upper-lower direction. The busbar **17** extends in an oblique direction inclined at a predetermined angle with respect to the front-rear direction. The oblique direction is an example of a second direction. The busbar **11** has a

through hole **111** at a rear end portion for attachment to a component, and a front end portion thereof is joined to an upper end face of the busbar **13**. A lower end face of the busbar **13** is joined to an upper face of a rear end portion of the busbar **15**.

[0029] The busbar **15** includes a body portion **151** extending in the front-rear direction, and a recessed portion **152** that is recessed in the front-rear direction at one end portion, that is, a front end portion of the body portion **151** in the front-rear direction. The body portion **151** is an example of a first body portion. The busbar **17** includes a body portion **171** extending in the oblique direction, and a protruding portion **172** that protrudes in the oblique direction from one end portion, that is, a rear end portion of the body portion **171** in the oblique direction. The recessed portion **152** and the protruding portion **172** have such shapes that allow the busbar **17** to rotate relatively to the busbar **15** around the protruding portion **172** as an axis in a horizontal plane, that is, a plane that includes the front-rear direction and the oblique direction. The recessed portion **152** and the protruding portion **172** are joined together.

[0030] The recessed portion **152** has a concave arc-shaped end face **15***a*. The protruding portion **172** has a convex arc-shaped end face **17***a* corresponding to the concave arc shape of the end face **15***a*. The end face **15***a* is an example of a first end face, and the end face **17***a* is an example of a second end face. The recessed portion **152** and the protruding portion **172** have respective concave and convex arc-shaped end faces **15***a* and **17***a* having substantially the same diameter dimension, and are therefore rotatable in a state of abutting against each other. The concave and convex arc-shaped end faces **15***a*, **17***a* are configured such that a diameter of the convex arc-shaped end face **17***a* is slightly smaller than that of the concave arc-shaped end face **15***a*. Therefore, the busbar **15** and the busbar **17** can be coupled such that the body portions **151** and **171** are arranged at a predetermined angle in a state where the end faces **15***a* and **17***a* are abutting against each other.

[0031] In the busbar coupling structure **1**, the recessed portion **152** and the protruding portion **172** have such shapes that allow the busbar **17** to rotate relatively to the busbar **15** around the protruding portion **172** as an axis in a horizontal plane, that is, a plane that includes the front-rear direction and the oblique direction, and the recessed portion **152** and the protruding portion **172** are joined together. According to this configuration, a coupling angle between the busbar **15** and the busbar **17** can be adjusted, so that the versatility of the busbar coupling structure **1** can be improved. In addition, since the busbar **15** and the busbar **17** are connected in the same plane, it is possible to reduce a space in the thickness (plate thickness) direction, that is, the upper-lower direction, as compared with a case where the busbar **15** and the busbar **17** are connected in an overlapping manner. Further, the busbar **15** and the busbar **17** are joined to each other by the arcuate faces, so that a joining area is large and stable conduction is enabled.

[0032] A recessed portion similar to the recessed portion **152** of the busbar **15** is provided on a front end portion of the busbar **17**. The busbar **19** is provided with a protruding portion similar to the protruding portion **172** of the busbar **17** at a rear end portion, and has a through hole **191** for attachment to a component at a front end portion. The recessed portion and the protruding portion have such shapes that allow the busbar **19** to rotate relatively to the busbar **17** around the protruding portion as an axis in the horizontal plane. Accordingly, a coupling angle between the busbar **17** and the busbar **19** can be adjusted. The busbar **17** and the busbar **19** are arranged such that the body portions **151** and **171** are at a predetermined angle, and the recessed portion **152** and the protruding portion **172** are joined to each other. By joining the busbar **17** and the busbar **19** in this manner, it is possible to reduce the space in the thickness direction as compared with the case where the busbar **17** and the busbar **19** are connected in an overlapping manner. The busbar **17** is an example of the first busbar, and the busbar **19** is an example of the second busbar.

[0033] As shown in FIG. **3**, the convex arc-shaped end face **17***a* of the busbar **17** has an arc width WA that is equal to or smaller than a width WB that is the dimension of the body portion **171** in a width direction, and an arc opening angle θ, which is an angle around a center point O, is approximately 270 degrees. As shown in FIG. **3**, the busbar **17** has a notch **173** between the body

portion **171** and the end face **17***a*. By providing the notch **173**, a length of the convex arc of the end face **17***a*, that is, a length of the end face **17***a* in the horizontal plane can be increased, and the busbar **17** becomes rotatable relative to busbar **15** to a position where a tip portion **153** comes into contact with the notch **173**. That is, a rotatable range of the busbar **17** relative to the busbar **15** can be increased. Accordingly, the versatility of the busbar coupling structure **1** can be improved. The tip portion **153** is formed by the left and right side faces at the front end portion of the body portion **151** of the busbar **15** and the left and right end portions of the recessed portion **152**. The notch **173** is formed in a shape and size capable of receiving the tip portion **153**. Since the end face **17***a* has an arc opening angle θ of 225 degrees or more and 315 degrees or less, the rotatable range of the busbar **17** relative to the busbar **15** can be increased, and the strength of the connection between the protruding portion **172** and the body portion **171** via the notch **173** can be ensured.

[0034] The busbar coupling structure **1** configured as described above is formed by joining the busbar **11**, the busbar **15**, the busbar **17**, and the busbar **19** together. In the busbar coupling structure **1**, the busbar **11** and the busbar **19** are attached to various components through the through hole **111** and the through hole **191**, respectively, to enable electrical continuity between the components. At a butt joint portion between adjacent busbars among the busbars **15**, **17**, and **19**, one busbar has the convex arc-shaped end face **17***a*, **19***a*, while the other busbar has the concave arc-shaped end face **15***a*, **17***b* that has substantially the same diameter as the convex arc. Since the joining faces of the busbars **15**, **17**, and **19** have an arc shape, there is no need to provide inclined end faces with different angles according to the wiring direction, and the busbars can be joined in various directions on the arc. As described above, in the busbar coupling structure **1**, since the busbars are joined to each other by the arcuate faces, a rotation direction can be freely adjusted for joining, so that the busbar can be attached to components with different paths, and the versatility is improved. Further, in the busbar coupling structure **1**, since the busbars are joined to each other by the arcuate faces, the joining area is larger than that of a normal butt joint, and stable conduction is enabled.

Second Embodiment

[0035] FIG. **4** is a perspective view showing a busbar coupling structure according to a second embodiment. FIG. **5** is an exploded perspective view of the busbar coupling structure shown in FIG. **4**. FIG. **6** is an enlarged top view of a part of the busbar coupling structure shown in FIG. **4**. Hereinafter, for convenience of description, as shown in FIG. **5**, a "front-rear direction", a "left-right direction", and an "upper-lower direction" are defined. The "front-rear direction", the "left-right direction", and the "upper-lower direction" are orthogonal to one another. In the second embodiment, the same members and portions as those shown in FIGS. **1** to **4** are denoted by the same reference numerals, and redundant description thereof will be omitted.

[0036] A busbar coupling structure **1**A includes busbars **15**A, **17**A, and **19**A as shown in FIG. **4**, instead of the busbars **15**, **17**, and **19** in the busbar coupling structure **1** shown in FIGS. **1** to **3**.

[0037] The busbar **15**A includes a body portion **151**A extending in the front-rear direction, and a recessed portion **152**A that is recessed in the front-rear direction at one end portion, that is, a front end portion of the body portion **151**A in the front-rear direction. The body portion **151**A is an example of the first body portion. The busbar **17**A includes a body portion **171**A extending in the oblique direction, and a protruding portion **172**A that protrudes in the oblique direction from one end portion, that is, a rear end portion of the body portion **171**A in the oblique direction. The recessed portion **152**A and the protruding portion **172**A have such shapes that allow the busbar **17**A to rotate relatively to the busbar **15**A around the protruding portion **172**A as an axis in a horizontal plane, that is, a plane that includes the front-rear direction and the oblique direction. The recessed portion **152**A and the protruding portion **172**A are joined together.

[0038] The recessed portion **152**A has a concave arc-shaped end face **15**Aa. The protruding portion **172**A has a convex arc-shaped end face **17**Aa corresponding to the concave arc shape of the end face **15**Aa. The end face **15**Aa is an example of the first end face, and the end face **17**Aa is an example of the second end face. The recessed portion **152**A and the protruding portion **172**A have

respective concave and convex arc-shaped end faces **15**Aa and **17**Aa having substantially the same diameter dimension as the convex arc, and are therefore rotatable in a state of abutting against each other. The concave and convex arc-shaped end faces **15**Aa, **17**Aa are configured such that a diameter of the convex arc-shaped end face **17**Aa is slightly smaller than that of the concave arc-shaped end face **15**Aa. Therefore, the busbar **15**A and the busbar **17**A can be coupled such that the body portions **151**A and **171**A are arranged at a predetermined angle in a state where the end faces **15**Aa and **17**Aa are abutting against each other.

[0039] In the busbar coupling structure **1**A, the recessed portion **152**A and the protruding portion **172**A have such shapes that allow the busbar **17**A to rotate relatively to the busbar **15**A around the protruding portion **172**A as an axis in a horizontal plane, that is, a plane that includes the front-rear direction and the oblique direction, and the recessed portion **152**A and the protruding portion **172**A are joined together. According to this configuration, a coupling angle between the busbar **15**A and the busbar **17**A can be adjusted, so that the versatility of the busbar coupling structure **1**A can be improved. In addition, since the busbar **15**A and the busbar **17**A are connected in the same plane, it is possible to reduce a space in the thickness direction, that is, the upper-lower direction, as compared with a case where the busbar **15**A and the busbar **17**A are connected in an overlapping manner. Further, the busbar **15**A and the busbar **17**A are joined to each other by the arcuate faces, so that a joining area is large and stable conduction is enabled.

[0040] A recessed portion similar to the recessed portion **152**A of the busbar **15**A is provided on a front end portion of the busbar **17**A. The busbar **19**A is provided with a protruding portion similar to the protruding portion **172**A of the busbar **17**A at a rear end portion, and has a through hole **19**A**1** for attachment to a component at a front end portion. The recessed portion and the protruding portion have such shapes that allow the busbar **19**A to rotate relatively to the busbar **17**A around the protruding portion as an axis in the horizontal plane. Accordingly, a coupling angle between the busbar **17**A and the busbar **19**A can be adjusted. The busbar **17**A and the busbar **19**A are arranged such that the body portions **151**A and **171**A are at a predetermined angle, and the recessed portion **152**A and the protruding portion **172**A are joined to each other. By joining the busbar **17**A and the busbar **19**A in this manner, it is possible to reduce the space in the thickness direction as compared with the case where the busbar **17**A and the busbar **19**A are connected in an overlapping manner. The busbar **17**A is an example of the first busbar, and the busbar **19**A is an example of the second busbar.

[0041] As shown in FIG. **6**, the convex arc-shaped end face **17**Aa of the busbar **17**A has an arc width WA that is greater than the width WB that is the dimension of the body portion **171**A in the width direction, and an arc opening angle θ, which is an angle around a center point O, is approximately 270 degrees. Since the arc width WA of the end face **17**Aa is greater than the width WB of the body portion **171**A, a rotatable range of the busbar **17**A relative to the busbar **15**A is increased. Accordingly, the versatility of the busbar coupling structure **1**A can be improved. Since the end face **17**Aa has an arc opening angle θ of 225 degrees or more and 315 degrees or less, the rotatable range of the busbar **17**A relative to the busbar **15**A can be sufficiently increased, which is advantageous in practical use.

[0042] The busbar coupling structure **1**A configured as described above is formed by joining the busbar **11**, the busbar **15**A, the busbar **17**A, and the busbar **19**A together. In the busbar coupling structure **1**A, the busbar **11** and the busbar **19**A are attached to various components through the through hole **111** and the through hole **19**A**1**, respectively, to enable electrical continuity. At a butt joint portion between adjacent busbars among the busbars **15**A, **17**A, and **19**A, one busbar has the end face **17**Aa, **19**Aa each having a convex arc shape with a diameter larger than the width of the busbar body portion, while the other busbar has the concave arc-shaped end face **15**Aa, **17**Ab that has substantially the same diameter as the convex arc. Since the joining faces of the busbars **15**A, **17**A, and **19**A have an arc shape, there is no need to provide inclined end faces with different angles according to the wiring direction, and the busbars can be joined in various directions on the

arc. As described above, in the busbar coupling structure **1**A, since the busbars are joined to each other by the arcuate faces, a rotation direction can be freely adjusted for joining, so that the busbar can be attached to components with different paths, and the versatility is improved. Further, in the busbar coupling structure **1**A, since the busbars are joined to each other by the arcuate faces, the joining area is larger than that of a normal butt joint, and stable conduction is enabled.

[0043] The present invention is not limited to the above-described embodiments, and can be appropriately modified, improved, or the like. In addition, the material, shape, size, numerical value, form, number, arrangement position, and the like of components in the above-described embodiments are freely selected and are not limited as long as the present invention can be achieved. In each of the above-described embodiments, the one end face **17***a*, **17**Aa of the busbar **17**, **17**A has a convex arc shape and the other end face **17***b*, **17**Ab of the busbar **17**, **17**A has a concave arc shape. Alternatively, both end faces may have a convex arc shape, or both end faces may have a concave arc shape.

[0044] Further, in each of the above-described embodiments, the recessed portion **152**, **152**A of the busbar **15**, **15**A and the protruding portion **172**, **172**A of the busbar **17**, **17**A are joined by the concave arc-shaped end face **15***a*, **15**Aa and the convex arc-shaped end face **17***a*, **17**Aa. However, the shapes of the recessed portion and the protruding portion are not limited to arc shapes. The recessed portion and protruding portion may have any shape that allows one busbar to rotate relative to the other busbar in a horizontal plane, and may be, for example, a polygonal or gear shape.

[0045] Here, features of the busbar coupling structure according to the embodiments of the present invention described above are briefly summarized and listed in the following [1] to [5].

[0046] [1] A busbar coupling structure (**1**, **1**A) including: [0047] a first busbar (busbar **15**) having a first body portion (body portion **151**) extending in a first direction (front-rear direction), and a recessed portion (**152**) that is recessed in the first direction at one end portion of the first body portion in the first direction; and [0048] a second busbar (busbar **17**) having a second body portion (body portion **171**) extending in a second direction, and a protruding portion (**172**) that protrudes in the second direction from one end portion of the second body portion in the second direction, in which [0049] the recessed portion and the protruding portion have such shapes that allow the second busbar to rotate relatively to the first busbar around the protruding portion as an axis in a plane that includes the first direction and the second direction, and [0050] the recessed portion and the protruding portion are jointed to each other.

[0051] According to the busbar coupling structure having the configuration of the above [1], the recessed portion and the protruding portion have such shapes that allow the second busbar to rotate relatively to the first busbar around the protruding portion as an axis in the plane that includes the first direction and the second direction, and the recessed portion and the protruding portion are jointed to each other. According to this configuration, a coupling angle between the first busbar and the second busbar can be adjusted, so that the versatility of the busbar coupling structure can be improved. In addition, since the first busbar and the second busbar are connected in the same plane, it is possible to reduce a space in the thickness direction as compared with a case where the first busbar and the second busbar are connected in an overlapping manner.

[0052] [2] In the busbar coupling structure according to [1], [0053] the recessed portion (**152**) has a first end face (end face **15***a*, **15**Aa) having a concave arc shape, and [0054] the protruding portion (**172**) has a second end face (end face **17***a*, **17**Aa) having a convex arc shape corresponding to the concave arc shape.

[0055] According to the busbar coupling structure having the configuration of the above [2], since the first busbar and the second busbar are joined to each other by the arcuate faces, the joining area is large and stable conduction is enabled.

[0056] [3] In the busbar coupling structure according to [2], [0057] the second end face (end face **17***a*) has an arc width (WA) equal to or smaller than a dimension (width WB) of the second body

portion (body portion **171**) in a width direction intersecting the second direction, and an arc opening angle (**0**) of 225 degrees or more and 315 degrees or less, and [0058] the second busbar (busbar **17**) has a notch between the second body portion and the second end face.
[0059] According to the busbar coupling structure having the configuration of the above [3], since the second busbar has the notch between the second body portion and the second end face, a length of the convex arc of the second end face can be increased, and the second busbar can rotate relative to the first busbar to a position where a tip portion of the first busbar comes into contact with the notch. That is, a rotatable range of the second busbar relative to the first busbar can be increased. Accordingly, the versatility can be improved. Further, the arc opening angle is 225 degrees or more and 315 degrees or less, so that the rotatable range of the second busbar relative to the first busbar can be increased, and the strength of the connection between the protruding portion and the second body portion via the notch can be ensured.
[0060] [4] In the busbar coupling structure according to [2], [0061] an arc width (WA) of the second end face is larger than a dimension (width WB) of the second body portion in a width direction intersecting the second direction.
[0062] According to the busbar coupling structure having the configuration of the above [4], since the arc width of the second end face having the convex arc shape is larger than the width of the second body portion, the rotatable range of the second busbar relative to the first busbar can be increased. Accordingly, the versatility can be improved.
[0063] [5] In the busbar coupling structure according to any one of [1] to [4], [0064] the first busbar and the second busbar are busbars for supplying vehicle driving power.
[0065] According to the busbar coupling structure having the configuration of the above [5], the busbar coupling structure can be used, for example, for electrical connection in a high-voltage battery pack mounted on a vehicle.
[0066] The present application is based on a Japanese patent application (Japanese Patent Application No. 2022-197910) filed on Dec. 12, 2022, and the contents thereof are incorporated herein by reference.
Industrial Applicability
[0067] According to the present invention, it is possible to provide a busbar coupling structure that can improve versatility and save space. The present invention having this effect is useful in relation to a busbar coupling structure.

Claims

1. A busbar coupling structure comprising: a first busbar having a first body portion extending in a first direction, and a recessed portion that is recessed in the first direction at one end portion of the first body portion in the first direction; and a second busbar having a second body portion extending in a second direction, and a protruding portion that protrudes in the second direction from one end portion of the second body portion in the second direction, wherein the recessed portion and the protruding portion have such shapes that allow the second busbar to rotate relatively to the first busbar around the protruding portion as an axis in a plane that includes the first direction and the second direction, and wherein the recessed portion and the protruding portion are jointed to each other.
2. The busbar coupling structure according to claim 1, wherein the recessed portion has a first end face having a concave arc shape, and wherein the protruding portion has a second end face having a convex arc shape corresponding to the concave arc shape.
3. The busbar coupling structure according to claim 2, wherein the second end face has an arc width equal to or smaller than a dimension of the second body portion in a width direction intersecting the second direction, and an arc opening angle of 225 degrees or more and 315 degrees or less, and wherein the second busbar has a notch between the second body portion and the 25

second end face.

4. The busbar coupling structure according to claim 2, wherein an arc width of the second end face is larger than a dimension of the second body portion in a width direction intersecting the second direction.

5. The busbar coupling structure according to claim 1, wherein the first busbar and the second busbar are busbars for supplying vehicle driving power.