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(54) **ELECTRIC WIRE WITH TERMINAL AND METHOD FOR MANUFACTURING THE SAME**

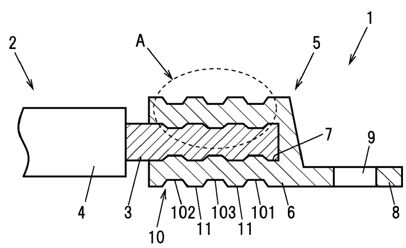
(57) An electric wire with terminal (1) includes an electric wire (2) including a conductor (3) and an insulating layer (4) covering the conductor (3), and a terminal (5) including a hollow portion (7) into which the conductor (3) exposed at an end portion of the electric wire (2) is inserted. The terminal (5) is connected to the conductor (3) by compressing the hollow portion (7) with the conductor (3) being inserted into the hollow portion (7). A tensile strength of a material used for the conductor (3) is greater than a tensile strength of a material used for the terminal (5). The terminal (5) includes at least three compressed portions (10) in a longitudinal direction of the conductor (3). When a cross-sectional area of the conductor (3) is S (mm^2), a compression width which is a length in the longitudinal direction of the compressed portion (10) is W (mm), and a compression interval which is a length in the longitudinal direction of a non-compressed portion (11) located between adjacent compressed portions (10) is L (mm), the compression width W and the compression interval L, respectively, satisfy formulas (1) and (2):

$$0.01 \times S + 2.5 \leq W \leq 0.07 \times S + 3.5 \cdots (1), \qquad (1),$$

and

$$-1.0 \leq L \leq 0.145 \times S + 3.75 \cdots (2). \qquad (2).$$

FIG. 1A



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Description

Cross-Reference to Related Application

[0001] The present application is based on Japanese patent application No.2020-119682 filed on July 13, 2020, the entire contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

[0002] The present invention relates to an electric wire with terminal and a method for manufacturing the same.

2. DESCRIPTION OF THE RELATED ART

[0003] Conventionally, in an electric wire with terminal including an electric wire and a terminal connected to a conductor of the electric wire, a conductor and a terminal respectively formed from copper or copper alloy have been used from the perspective of electrical conductivity. In recent years, from the viewpoint of weight reduction, it has been studied to form the conductor and the terminal from aluminum materials (aluminum or aluminum alloy).
[0004] For example, WO98/54790 is one of the prior art documents related to the invention of the present application.
[0005] [Patent Document 1] WO98/54790

SUMMARY OF THE INVENTION

[0006] In an electric wire with terminal, the stress acting on a connecting portion between the conductor and the terminal decreases over time, which in turn reduces the contact force between the conductor and the terminal and may increase the electric resistance between the conductor and the terminal. In particular, the stress relaxation in aluminum is more likely to occur than the stress relaxation in copper, and the above problems are more likely to arise when a terminal made of aluminum is connected to a conductor made of aluminum. With a high electric resistance between the conductor and the terminal, passing electric current through the conductor generates heat in the electric wire with terminal, which may cause an electric wire break or poor contact.
[0007] In light of the foregoing, the object of the present invention is to provide an electric wire with terminal that can maintain a low electric resistance between the conductor and the terminal, and to ensure adequate electrical connections, and a method for manufacturing the same.
[0008] For solving the above problem, one aspect of the present invention provides: An electric wire with terminal **(1),** comprising:

an electric wire **(2)** including a conductor **(3)** and an insulating layer **(4)** covering the conductor **(3);** and
a terminal **(5)** including a hollow portion **(7)** into which the conductor **(3)** exposed at an end portion of the electric wire **(2)** is inserted,
wherein the terminal **(5)** is connected to the conductor **(3)** by compressing the hollow portion **(7)** with the conductor **(3)** being inserted into the hollow portion **(7),**
wherein a tensile strength of a material used for the conductor **(3)** is greater than a tensile strength of a material used for the terminal **(5),**
wherein the terminal **(5)** includes at least three compressed portions **(10)** in a longitudinal direction of the conductor **(3),**
wherein a cross-sectional area of the conductor **(3)** is S (mm^2), a compression width which is a length in the longitudinal direction of the compressed portion **(10)** is W (mm), and a compression interval which is a length in the longitudinal direction of a non-compressed portion **(11)** located between adjacent compressed portions **(10)** is L (mm), wherein the compression width W and the compression interval L, respectively, satisfy formulas **(1)** and **(2):**

$$0.01 \times S + 2.5 \leq W \leq 0.07 \times S + 3.5 \cdot\cdot\cdot (1),$$

and

$$-1.0 \leq L \leq 0.145 \times S + 3.75 \cdot\cdot\cdot (2).$$

[0009] Another aspect of the present invention provides: A method for manufacturing an electric wire with terminal **(1)** comprising an electric wire **(2)** including a conductor **(3)** and an insulating layer **(4)** covering the conductor **(3),** and a terminal **(5)** including a hollow portion **(7)** into which the conductor **(3)** exposed at an end portion of the electric wire **(2)** is inserted, wherein the terminal **(5)** is connected to the conductor **(3)** by compressing the hollow portion **(7)** with the conductor **(3)** being inserted into the hollow portion **(7),**
the method comprising:

preparing the electric wire **(2)** and the terminal **(5),** wherein a tensile strength of a material used for the conductor **(3)** is greater than a tensile strength of a material used for the terminal **(5);** and
connecting the terminal **(5)** to the conductor **(3)** by compressing the terminal **(5)** with the conductor **(3)** being inserted in the hollow portion **(7)** at least three times, to form at least three compressed portions **(10)** at the terminal **(5),**
wherein the at least three compressed portions **(10)** are formed by forming adjacent compressed portions **(10)** and thereafter forming an other compressed portion **(10)** between the adjacent compressed portions **(10),**
wherein the compressed portion is formed in such a manner than a cross-sectional area of the conductor **(3)** is S (mm^2), a compression width which is a length in a longitudinal direction of the compressed portion **(10)** is W (mm), and a compression interval which is a length in the longitudinal direction of a non-compressed portion **(11)** located between adjacent compressed portions **(10)** is L (mm), wherein the compression width W and the compression interval L, respectively, satisfy formulas **(1)** and **(2):**

$$\mathbf{0.01} \times \mathrm{S} + \mathbf{2.5} \le \mathrm{W} \le \mathbf{0.07} \times \mathrm{S} + \mathbf{3.5} \cdot\cdot\cdot (\mathbf{1}),$$

and

$$\mathbf{-1.0} \le \mathrm{L} \le \mathbf{0.145} \times \mathrm{S} + \mathbf{3.75} \cdot\cdot\cdot (\mathbf{2}).$$

Points of Invention

[0010] According to the invention, it is possible to provide an electric wire with terminal that can maintain a low electric resistance between the conductor and the terminal, and to ensure adequate electrical connections, and a method for manufacturing the same.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Next, preferred embodiment according to the present invention will be described with reference to appended drawings, wherein:

FIG. 1A is a cross-sectional view of an electric wire with terminal in a preferred embodiment of the present invention;
FIG. 1B is an enlarged view of a section A of the electric wire with terminal in FIG. **1A;**
FIGS. 2A to **2**C are explanatory diagrams showing a method for manufacturing the electric wire with terminal;
FIGS. 3A and **3**B are explanatory diagrams showing the behavior of a terminal and a conductor when forming a third compressed portion;
FIG. 4 is a schematic diagram for explaining an outline of high-temperature environmental exposure test;
FIG. 5 is a schematic diagram for explaining a measuring method of an electric resistance ratio;
FIG. 6A is a graph showing the results of measuring the electric resistance ratio R**2** after the high-temperature environmental exposure test when a compression width W is changed;
FIG. 6B is a graph showing the results of measuring the electric resistance ratio R**2** after the high-temperature environmental exposure test when a compression interval L is changed;
FIG. 6C is an explanatory diagram showing the overlapping state;
FIG. 7A is a graph showing the results of the measurement of a resistance ratio-increase rate (rate of increase in electric resistance ratio) after the high-temperature environmental exposure test when the compression width W is changed;
FIG. 7B is a graph showing the results of the measurement of the resistance ratio-increase rate after the high-temperature environmental exposure test when compression interval L is changed;
FIG. 8A is a graph showing the relationship between a conductor cross-sectional area S and the compression width W, which shows a region where the electric resistance ratio R**2** is **100%** or less after the high-temperature environmental exposure test;

FIG. 8B is a graph showing the relationship between the conductor cross-sectional area S and the compression interval L, which shows a region where the electric resistance ratio R**2** is **100%** or less after the high-temperature environmental exposure test;

FIG. 9A is a graph showing the relationship between the conductor cross-sectional area S and the compression width W, which shows a region where the electric resistance ratio R**2** after the high-temperature environmental exposure test is **100**% or less and the resistance ratio-increase rate is **20**% or less; and

FIG. 9B is a graph showing the relationship between the conductor cross-sectional area S and the compression interval L, which shows a region where the electric resistance ratio R**2** after the high-temperature environmental exposure test is **100**% or less and the resistance ratio-increase rate is **20**% or less.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[Embodiment]

[0012] Next, an embodiment of the present invention will be described below in conjunction with the accompanying drawings.

(Schematic configuration of an electric wire with terminal)

[0013] **FIG. 1**A is a cross-sectional view of an electric wire with terminal in a preferred embodiment of the present invention, and **FIG. 1**B is an enlarged view of a section A of the electric wire with terminal in **FIG. 1**A. As shown in **FIGS. 1**A and **1**B, an electric wire with terminal **1** includes an electric wire **2** and a terminal **5.** The electric wire with terminal **1** can be used as a wiring material for buildings, wind generators, railcars (rolling stocks), automobiles, and so on.

[0014] The electric wire **2** includes a conductor **3** and an insulating layer **4** covering the conductor **3.** As the conductor **3,** a metal wire, a stranded wire made of plural metal strands (elementary wires) stranded together, or a composite stranded wire made of plural stranded wires stranded together may be used. As the metal materials for forming the conductor **3,** e.g., pure aluminum or aluminum alloys (hereafter referred to as "aluminum material") may be used. Pure aluminum is a material composed of Al and inevitable impurities.

[0015] As pure aluminum, e.g., pure aluminum for electrical purpose (ECA1) may be used. As aluminum alloys, e.g., Al-Zr, Al-Fe-Zr, etc. as below may be used. Al-Zr is aluminum alloy with a chemical composition composed of **0.03** to **1.5** mass% (% by mass) of Zr, **0.1** to **1.0** mass% of Fe and Si, and the balance of Al and inevitable impurities. Al-Fe-Zr is aluminum alloy with a chemical composition composed of **0.01** to **0.10** mass% of Zr, **0.1** mass% or less of Si, **0.2** to **1.0** mass% of Fe, **0.01** mass% or less of Cu, **0.01** mass% or less of Mn, **0.01** mass% or less of Mg, **0.01** mass% or less of Zn, **0.01** mass% or less of Ti, **0.01** mass% or less of V, and the balance of Al and inevitable impurities. In Al-Zr, "**0.1** to **1.0** mass% of Fe and Si" means that when both Fe and Si are included, a total concentration of Fe and Si is **0.1** to **1.0** mass%, when Fe is included but Si is not included, a concentration of Fe is **0.1** to **1.0** mass%, and when Si is included but Fe is not included, a concentration of Si is **0. 1** to **1.0** mass%. In this context, "not included" means that, for example, the concentration is less than or equal to the detection limit of the high-frequency inductively coupled plasma emission spectroscopy.

[0016] An insulating layer **4** is composed of, e.g., fluorine resin, olefin resin, silicone resin or the like. Although the insulating layer **4** is provided over an entire length in a longitudinal direction of the electric wire **2,** in the present embodiment, the insulating layer **4** is removed from the electric wire **2** for a given length from an end portion of the electric wire **2,** and an end portion of the conductor **3** is partially exposed (Hereinafter, also referred to as "the exposed conductor **3**").

[0017] The terminal **5** includes a tubular portion **6** having a hollow portion **7** and an extending portion **8,** which are formed integrally (as one piece). The terminal **5,** for example, may include a plate-like extending portion **8** which is formed by press-machining one end of a pipe. Alternatively, the terminal **5,** for example, may include the tubular portion **6** formed by boring one end of a cylindrical base material and the extending portion **8** formed by pressing the other end of the cylindrical base material. The hollow portion **7** has a cylindrical shape opened at one side.

[0018] The terminal **5** is composed of, e.g., aluminum material. More specifically, pure aluminum or aluminum alloy is preferred, for example. Pure aluminum is a material composed of A1 and inevitable impurities. As pure aluminum, e.g., pure aluminum for electrical purpose (ECA1) may be used. As aluminum alloy, e.g., Al-Fe-Zr as below may be used. Al-Fe-Zr is aluminum alloy with a chemical composition composed of **0.01** to **0.10** mass% of Zr, **0.1** mass% or less of Si, **0.2** to **1.0** mass% of Fe, **0.01** mass% or less of Cu, **0.01** mass% or less of Mn, **0.01** mass% or less of Mg, **0.01** mass% or less of Zn, **0.01** mass% or less of Ti, **0.01** mass% or less of V, and the balance of Al and inevitable impurities.

[0019] The tubular portion **6** is formed in a tubular shape having a circular cross section, within which the hollow portion **7** is formed. The hollow portion **7** is configured in such a manner that the conductor **3** exposed at the end portion of the electric wire **2** can be inserted into the hollow portion **7.** The tubular portion **6** is opened in such a manner that an inner diameter N (mm) of the tubular portion **6** has a size ranging from a size corresponding (equivalent) to an outer diameter of the conductor **3** to **90%** to **95%** of the outer diameter of the conductor **3.** Through the opening of the hollow portion **7,** the conductor **3** exposed at the end portion of the electric wire **2** is inserted into the hollow portion **7.** When inserting the conductor **3** through the opening of the hollow portion **7,** if the outer diameter of the conductor **3** is compressed to have a size substantially equal to the inner diameter of the tubular portion **6,** the damage to the conductor **3** will be reduced, and the conductor **3** can be inserted smoothly into the hollow portion **7.** Also, a thickness A (mm) of the tubular portion **6** is determined from a ratio of a cross-sectional area of the tubular portion **6** corresponding to a non-compressed portion **11** of the terminal **5** and a cross-sectional area of the conductor **3** corresponding to the non-compressed portion **11** of the terminal **5,** in a cross section normal to the longitudinal direction of the conductor **3,** when the terminal **5** with the hollow portion **7** into which the conductor **3** is inserted is compressed. In other words, the thickness A (mm) of the tubular portion **6** is determined by the formula (T/S), where the cross-sectional area of the tubular portion **6** at the non-compressed portion **11** of the terminal **5** is T (mm^2) and the cross-sectional area of the conductor **3** at the non-compressed portion **11** of the terminal **5** is S (mm^2). The range of this ratio (T/S) is preferably **1.0** or more and **3.0** or less. If this ratio (T/S) is less than **0,** the thickness A of the tubular portion **6** will be small and the compression may cause the tubular portion **6** to stretch and break. If this ratio (T/S) exceeds **3.0,** the tubular portion **6** will be mainly compressed and the conductor **3** will not be sufficiently compressed, which may result in insufficient mechanical joints. The cross-sectional area T (mm^2) of the tubular portion **6** corresponding to the non-compressed portion **11** of the terminal **5** is calculated as $T = ((2A+N)/2)^2-(N/2)^2) \times \pi$. The thickness A of the tubular portion **6** can be derived from the cross-sectional area T of the tubular portion **6** and the inner diameter N of the tubular portion **6,** which can be calculated from the ratio (T/S) of the cross-sectional area T of the tubular portion **6** corresponding to the non-compressed portion **11** of the terminal **5** and the cross-sectional area S of the conductor **3** corresponding to the non-compressed portion **11** of the terminal **5.**

[0020] A surface of the terminal **5** and an inner surface of the tubular portion **6** may be Sn-plated or Ag-plated. It is possible to apply a compound with conductive particles to the exposed conductor **3** and then insert the exposed conductor **3** into the hollow portion 7. Alternatively, the hollow portion **7** of the tubular portion **6** may be coated or filled with the compound before inserting the exposed conductor **3.** As the compound with conductive particles, fluorine oil or silicone oil including conductive particles of Ni-P or Ni-B, Ni, or Zn solely or in combination may be used. The terminal **5** is connected to the conductor **3** by compressing the hollow portion **7** (the tubular portion **6**) with the conductor **3** being inserted in the hollow portion **7.**

[0021] The extending portion **8** is configured as a part to be connected to a terminal, bolt, and the like of an external counterpart. In the present embodiment, the extending portion **8** is formed in a plate shape and provided with a bolt hole **9,** into which a bolt used for connection with an external terminal is inserted.

[0022] In the electric wire with terminal **1** according to the present embodiment, the tubular portion **6** of the terminal **5** has at least three compressed portions **10 in** the longitudinal direction of the conductor **3.** Although the case in which the three compressed portions **10** are formed will be explained herein, the number of the compressed portions **10** may be four or more. The tubular portion **6** includes a portion located between the adjacent compressed portions **10,** and such a portion is called as "non-compressed portion **11".** The compressed portion **10** is a part configured to be compressed by compression dies **20,** as described below, and has a substantially flat surface along the longitudinal direction. The non-compressed portion **11** is a portion that is configured not to be compressed by the compression dies **20** and has a larger outer diameter than the outer diameter of the compressed portion **10.** Between the compressed portion **10** and the non-compressed portion **11,** a tapered part is formed by compression (press deformation) with the use of the compression dies **20,** and this tapered part is included in the non-compressed portion **11.** Details of the compressed portion **10** and the non-compressed portion **11** will be described below.

[0023] In the compression step, a pair of compression dies **20** with half-divided structures are used. The pair of compression dies **20** are used to compress (press deformation, plastic deformation) a pressure-target portion of the tubular portion **6** by applying a predetermined pressure to the tubular portion **6** of the terminal **5.** The shape of each compression die **20** is, e.g., in a transverse view, a half-circle shape, a butt shape, hexagonal shape, and the like. Although the present invention is not particularly limited to the present embodiment, it is preferable that a compression ratio of the conductor **3** is **50%** or more and **95%** or less.

Here, the "compression ratio" is a ratio of a cross-sectional area of the conductor **3** corresponding to the non-compressed portion **11** of the terminal **5** and a cross-sectional area of the conductor **3** corresponding to the compressed portion **10** in the cross section normal to the longitudinal direction of the conductor **3** when the terminal **5** with the conductor **3** inserted in the hollow portion **7** is compressed. In other words, this compression ratio is calculated by the formula $(D/S) \times 100$, where the cross-sectional area of the conductor **3** corresponding to the non-compressed portion **11** of the terminal **5** is S (mm^2) and the cross-sectional area of the conductor **3** corresponding to the compressed portion **10** of the terminal **5** is D (mm^2). When the compression ratio falls within the above range, it is possible to suppress the drop in contact force between the conductor **3** and the terminal **5** due to stress relief of the conductor **3** and the terminal **5,** thereby reducing the increase in electric resistance ratio of the electric wire with terminal **1.** If plural metal strands are used as the conductor **3,** the cross-sectional area of the conductor **3** can be calculated by the product of the cross-sectional area of each metal strand and the number of metal strands.

(Method for manufacturing the electric wire with terminal)

[0024] When manufacturing the electric wire with terminal **1,** a preparation step for preparing the electric wire **2** and the terminal **5** is firstly performed. At this time, the materials for the conductor **3** and the terminal **5** should be selected in such a manner that the tensile strength of the material used for the conductor **3** is greater than the tensile strength of the material used for the terminal **5** (by e.g., **20**MPa or more). For example, if ECA1 is used as the material for the terminal **5,** Al-Fe-Zr (tensile strength difference: about **24**MPa or more) and Al-Zr (tensile strength difference: about **46**MPa or more) can be used as the material for the conductor **3.** In addition, even if the same material is used as the material of the conductor **3** and the material of the terminal **5,** the tensile strength of the material can be adjusted depending on the heat treatment condition and the degree of machining during the manufacturing process.

[0025] In the preparation step, the insulating layer **4** of the electric wire **2** is removed for a predetermined length from the terminal along the longitudinal direction of the electric wire **2,** thereby exposing a part of the conductor **3.** Then, the exposed part of the conductor **3** of the electric wire **2** is inserted into the hollow portion **7** formed in the tubular portion **6** of the terminal **5.**

[0026] Then, the connection step of connecting the terminal **5** to the conductor **3** is performed by compressing the tubular portion **6** of the terminal **5** at least three times to form at least three compressed portions **10** at the terminal **5** with the conductor **3** inserted in the hollow portion **7.** Here, the case where the tubular portion **6** of the terminal **5** is compressed three times to form three compressed portions **10** on the terminal **5** will be described below.

[0027] In the connection step, first, as shown in **FIG. 2**A**,** a portion near an extending portion **8**-side end portion of the tubular portion **6** (a near-end portion of the conductor **3**) is pressed by the compression dies **20,** so that the tubular portion **6** is compressed to form a first compressed portion **101.** Then, as shown in **FIG. 2**B, a portion near an opening-side end of the hollow portion **7** (on an insulating layer **4**-side) in the tubular portion **6** is pressed by the compression dies **20,** so that the tubular portion **6** is compressed to form a second compressed portion **102.**

[0028] Then, as shown in **FIG. 2**C, a portion at a location between the first compressed portion **101** and the second compressed portion **102** is pressed by the compression dies **20,** so that the tubular portion **6** is compressed to form a third compressed portion **103.** In this way, the connection step includes a step of forming the third compressed portion (another compressed portion) **103** between the already-formed adjacent first and second compressed portions **101, 102.** Between the first compressed portion **101** and the third compressed portion **103,** and between the third compressed portion **103** and the second compressed portion **102,** respectively, non-compressed portions **11** will be formed. Here, the case where the first compressed portion **101** is firstly formed then the second compressed portion **102** is formed is explained. However, after the second compressed portion **102** is formed, the first compressed portion **101** may be formed. The first compressed portion **101** and the second compressed portion **102** may be formed at the same time. In this case, the compression of the tubular portion **6** of the terminal **5** is performed at least two times to form at least three compressed portions **10** at the terminal **5.**

[0029] The first to third compressed portions **101** to **103** are formed by compressing the tubular portion **6** (press-deformation, plastic deformation) by applying a predetermined pressure all around the tubular portion **6** in a circumferential direction using the compression dies **20.** In the present embodiment, each of the first to third compressed portions **101** to **103** has a hexagonal cross section that is perpendicular to the longitudinal direction (axial direction) of the conductor **3.** By forming respective compressed portions **101** to **103,** it is possible to provide the electric wire with terminal **1** by compression-connecting the terminal **5** to the conductor **3.**

(Details of the compressed portion **10** and the non-compressed portion **11**)

[0030] Now, the behavior of the terminal **5** and the conductor **3** when forming the compressed portion **10** will be explained below. As shown in **FIG. 3**A, when the terminal **5** and the conductor **3** are pressed by the compression dies **20,** the effect of this pressure causes both the terminal **5** (the tubular portion **6**) and the conductor **3** to extend along the longitudinal direction. In the present embodiment, because the tensile strength of the material used for the terminal **5** is smaller than the tensile strength of the material used for the conductor **3,** the terminal **5** deforms more largely, and the difference in elongation between the terminal **5** and the conductor **3** is ΔL.

[0031] As shown in **FIG. 3**B**,** an initial state is the state where the first and second compressed portions **101, 102** are formed. In this state, a middle position between the first and the second compressed portions **101, 102** is pressed by the compression dies **20,** the terminal **5** will extend to be longer by ΔL than the conductor **3** due to the applied pressure. The contact force (axial contact force) between the terminal **5** and conductor **3** is generated at each of the first and second compressed portions **101, 102,** so that the contact resistance between the terminal **5** and the conductor **3** can be reduced.

[0032] This elongation difference ΔL between the terminal **5** and the conductor **3** increases the contact force (axial contact force) between the terminal **5** and the conductor **3** and reduces the contact resistance between the terminal **5** and the conductor **3.** The contact force between the terminal **5** and the conductor **3** will reduces due to changes in time.

However, in the present embodiment, the relaxation (loosening) of the contact force in the radial direction is supported by the contact force in the axial direction, by providing a force that allows the terminal **5** and the conductor **3** to pull each other not only in the radial direction but also in the longitudinal direction. Thus, the resistance value between the terminal **5** and the conductor **3** is suppressed from increasing over time.

[0033] To increase the contact force (axial contact force) between the terminal **5** and the conductor **3** and to reduce the contact resistance, it is enough to increase the elongation strain.

[0034] The elongation strain ε is expressed as below:

$$\varepsilon = \Delta L/L,$$

where the compression elongation difference is ΔL and a compression interval (an interval between the compressed portions **10** adjacent to each other in the longitudinal direction in **FIG. 3**B, i.e., a length in the longitudinal direction of the non-compressed portion **11**) is L.

[0035] Therefore, by increasing the compression elongation difference ΔL and reducing the compression interval L, the compression elongation strain can be increased, and the contact force (axial contact force) between the terminal **5** and the conductor **3** can be increased, so that the contact resistance between the terminal **5** and the conductor **3** can be further reduced.

[0036] In order to increase the elongation difference ΔL between the terminal **5** and the conductor **3** due to compression, a compression width W, which is a length in the longitudinal direction of the compressed portion **10,** can be set to an appropriate width according to the conductor cross-sectional area. The compression width W can be controlled by adjusting the size of the compression dies **20** to be used, and the compression interval L can be controlled by adjusting the positions of the respective compressed portions **101** to **103** (along the longitudinal direction of the conductor **3**).

[0037] The inventors conducted experiments to examine the effects of the compression width W and the compression interval L. First, the compression load by the compression dies **20** was constant at **12**t, the compression interval L (mm) was constant at **7** mm, and the compression width W (mm) was changed. In the experiment, samples of the electric wire **2** including the conductor **3** having the conductor cross-sectional areas of **50** mm^2 and **250** mm^2, respectively, were used. The compression ratio of **60**% to **95**% was set for the sample with the conductor cross-sectional area of **50** mm^2, and the compression ratio of **70%** to **95%** was set for the sample with the conductor cross-sectional area of **250** mm^2. In the case of using the electric wire **2** with the conductor cross-sectional area of **50** mm^2 (approximately **10** mm in diameter), the inner diameter N of the tubular portion **6** of the terminal **5** was **10.2** mm, and the thickness A of the tubular portion **6** was **3.0** mm. In the case of using the electric wire **2** with the conductor cross-sectional area of **250** mm^2 (approximately **23.6** mm in diameter), the inner diameter N of the tubular portion **6** of the terminal was **21.8** mm, and the thickness A of the tubular portion **6** was **5.2** mm (in the following experiments, the terminal **5** should have the same size). The larger the compression width W (mm), the larger the compression ratio of the conductor **3.**

(Measurement of the resistance ratio-increase rate)

[0038] Next, each of the samples for high-temperature environmental exposure testing was prepared by attaching an aluminum plate **13** to the extending portion **8** with a bolt (not shown), assuming that the extending portion **8** of the electric wire with terminal **1** configured to be connected to the conductor **3** by compressing the terminal **5** would be connected by a bolt or the like to a terminal of the external counterpart. As shown in **FIG. 4,** the high-temperature environment exposure test was performed in such a manner that the sample for the high-temperature environmental exposure test was placed in a thermostatic chamber **14** set at **200°C** and held for **100** hours in the atmosphere, and the sample was taken out from the thermostatic chamber **14** every **10** hours for detaching and attaching the bolt. The high-temperature environmental exposure test simulated the energizing test environment. **FIG. 4** shows that the aluminum plate **13** was fastened to a lower side of the extending portion **8.** However, even if the aluminum plate **13** was fastened to an upper side of the extending portion **8,** the result would be similar to that in the case where the aluminum plate **13** is fastened to the lower side of the extending portion **8.**

[0039] The ratio of electric resistance was measured before and after the high-temperature environmental exposure test, and the resistance ratio-increase rate was calculated from the ratio of electric resistance before and after the test. The resistance ratio-increase rate (%) can be calculated from the formula ((R**2**-R**1**)/R**1**) $\times$ **100,** where the electric resistance ratios between the conductor **3** and the terminal **5** before and after (i.e. after **100** hours hold) the high-temperature environmental exposure test are R**1** and R**2**, respectively.

(Measurement of the electric resistance)

[0040] Here, the electric resistance ratio (initial resistance ratio) R**1** was measured using the so-called "four-terminal method" prior to the high-temperature environmental exposure test of the electric wire with terminal 1. The four-terminal method will be explained below with referring to **FIG. 5.**

[0041] First, the entire electric wire with terminal **1** is supplied with a constant current **1**A and the electric resistance value R**0** between a point P and a point Q is measured. Here, the point P is one end of the tubular portion **6** of the terminal **5,** and is a part corresponding to the end portion of the inserted conductor **3.** The point Q is a part of the conductor **3** that is not in contact with the terminal **5.** A point S is the other end of the tubular portion **6** of the terminal **5,** and a part at the entrance where the conductor **3** is inserted. The initial resistance ratio R**1** (%) is calculated using the formula $\{(R0-L2 \times \alpha)/(L1 \times \alpha)\} \times 100$, where a distance between the point P and the point S is L**1**, a distance between the point Q and the point S is L**2**, and the electric resistance value per unit length of the conductor **3** is α. The electric resistance value per unit length of the conductor **3** may be measured in advance, or the electric resistance value between the point Q and the point S may be measured and divided by the length L**2** to be used as the electric resistance value per unit length.

[0042] In addition, the electric resistance ratio R**2** after the high-temperature environmental exposure test was measured using the same four-terminal method as when the electric resistance ratio (initial resistance ratio) was measured before the test, after cooling the electric wire with terminal **1** to room temperature. Specifically, the electric resistance value R between the point P and the point Q is measured by supplying a constant current **1**A to the entire electric wire with terminal **1** after the high-temperature environmental exposure test. The electric resistance value α per unit length of the conductor **3** should remain the same before and after the high-temperature environmental exposure test. The electric resistance ratio R**2** (%) is calculated as $\{(R-L2 \times \alpha)/(L1 \times \alpha)\} \times 100$. The electric resistance value was measured using an ohmmeter made by Hioki Electric Co., Ltd. The experimental results of the electric resistance ratio R**2** after the high-temperature environmental exposure test (after **100** hours hold) are shown in **FIG. 6**A.

[0043] As shown in **FIG. 6**A, the sample with the conductor **3** having the cross-sectional area of **50** mm^2 showed that the electric resistance ratio R**2** decreases with the compression width W being larger, but when the compression width W is too large, the electric resistance ratio R**2** changes to increase, and there is a certain compression width W where the electric resistance ratio R**2** becomes the minimum value. The sample of the conductor **3** having the cross-sectional area of **250** mm^2, the electric resistance ratio R**2** decreases with the compression width W being larger.

[0044] Similarly, the compression width W of the sample with the conductor **3** having the cross-sectional area of **50** mm^2 was set to **3** mm, the compression width W of the sample with conductor **3** having the cross-sectional area of **250** mm^2 was set to **7** mm, the compression load by the compression dies **20** was set to **12**t at constant, while the compression interval L was varied, to measure the electric resistance ratio R**2** after the high-temperature environmental exposure test. **FIG. 6**B shows the results of the experiment. In the sample with the conductor **3** having the cross-sectional area of **50** mm^2, it was found that the electric resistance ratio R**2** decreases with the compression interval L being larger, but when the compression interval L is set too large, the electric resistance ratio R**2** changes to increase, and there is a certain compression interval L where the electric resistance ratio R**2** becomes the minimum value. In the sample with the conductor **3** having the cross-sectional area of **250** mm^2, the electric resistance ratio R**2** decreases with the compression interval L being larger. In addition, **FIG. 6**B includes a region where the compression interval L is negative, which represents an overlapping state of the compressed portions **10. FIG. 6**C shows an overlapping state. The compression widths W of the first compressed portion **101,** second compressed portion **102,** and third compressed portion **103** pressed by the compression dies **20** are overlapping by the compression interval L. The compression interval L can be calculated as $L = (WL-3W)/2$, where the distance from the right edge of the first compressed portion **101** to the left edge of the second compressed portion **102** is WL. Here, if the compressed portions **10** are in an overlapping state, the value of the compression interval L is negative.

[0045] **FIG. 7**A is a graph showing the compression width W on the horizontal axis and the resistance ratio-increase rate on the vertical axis. The compression interval L of both the sample with the conductor **3** having the cross-sectional area of **50** mm^2 and the sample with the conductor **3** having the cross-sectional area of **250** mm^2 was set to **7**mm at constant, the compression load by the compression dies **20** was set to **12**t at constant, while the compression width W was varied, to measure the resistance ratio-increase rate before and after the high-temperature environmental exposure test. As shown in **FIG. 7**A, it was found that in both samples, the resistance ratio-increase rate decreases with the compression width W being larger, but the resistance ratio-increase rate changes to increase with the compression width W being too large, and there is the compression width W where the resistance ratio-increase rate becomes the minimum value.

[0046] **FIG. 7**B is a graph showing the compression interval L on the horizontal axis and the resistance ratio-increase rate on the vertical axis. Similarly, the compression width W of the sample with the conductor **3** having the cross-sectional area of **50** mm^2 was set to **3** mm at constant, the compression width W of the sample with conductor **3** having the cross-sectional area of **250** mm^2 was set to **7** mm at constant, the compression load by the compression dies **20** was set to **12**t at constant, while the compression interval L was varied, to the resistance ratio-increase rate before and after the high-temperature environmental exposure test.

[0047] As shown in **FIG. 7**B, in both the sample with the conductor **3** having the cross-sectional area of **50** mm^2 and the sample with the conductor **3** having the cross-sectional area of **250** mm^2, the resistance ratio-increase rate basically decreases with the compression interval L being smaller, but when the compression interval L is too small, the resistance ratio-increase rate changes to increase, and there is a certain compression interval L where the resistance ratio-increase rate becomes the minimum value. In addition, **FIG. 7**B includes a region where the compression interval L is negative, which represents an overlapping state of compressed portions **10.** The overlapping state in **FIG. 7**B is similar to the overlapping state shown in **FIG. 6**C. The compression widths W of the first compressed portion **101,** second compressed portion **102,** and third compressed portion **103** pressed by the compression dies 20 are overlapping by the compression interval L.

[0048] **FIG. 8**A is a graph showing the cross-sectional area S (mm^2) of the conductor **3** on the horizontal axis and the compression width W (mm) of the conductor **3** on the vertical axis. **FIG. 8**B is a graph showing the cross-sectional area S (mm^2) of the conductor **3** on the horizontal axis and the compression interval L (mm) of the conductor **3** on the vertical axis. Here, the inventors found the compression width W (mm) and the compression interval L (mm) that satisfy the electric resistance ratio R**2** after the high-temperature environmental exposure test being less than **100**% under conditions where the cross-sectional area of the conductor **3** is **38** mm^2 or more and **500** mm^2 or less. As a result, it was found that the electric resistance ratio R**2** after the high-temperature environmental exposure test was not more than **100**% when the compression width W (mm) meets the formula **(1)** below and the compression interval L (mm) meets the formula (2) below:

$$0.01 \times S + 2.5 \leq W \leq 0.07 \times S + 3.5 \cdot \cdot \cdot (1),$$

and

$$-1.0 \leq L \leq 0.145 \times S + 3.75 \cdot \cdot \cdot (2).$$

[0049] The region expressed by the formula **(1)** is shown as a hatched area in **FIG. 8**A. Similarly, the region expressed by the formula **(2)** is shown as a hatched area in **FIG. 8**B. For example, when the cross-sectional area S of the conductor **3** is **50** mm^2, it is possible to select the compression width W to be **3** mm or more and **7** mm or less, and the compression interval L to be **-1** mm or more and **11** mm or less. By using the compression width W and the compression interval L in the above regions, it is possible to achieve that the electric resistance ratio R**2** after the high-temperature environmental exposure test would be not more than **100**%.

[0050] The inventors further found better compression width W (mm) and compression interval L (mm). If both the conditions **(1)** and **(2)** as below are met, the selectable range will be smaller than the case where the compression width W and the compression interval L meet the target specifications for achieving that the electric resistance ratio R**2** after the high-temperature environmental exposure test would be **100**% or less:

(1) The electric resistance ratio R**2** after the high-temperature environmental exposure test is **100**% or less, and
(2) The resistance ratio-increase rate should be **20**% or less.

[0051] **FIG. 9**A is a graph showing the cross-sectional area S (mm^2) of the conductor **3** on the horizontal axis and the compression width W (mm) of the conductor **3** on the vertical axis. **FIG. 9**B is a graph showing the cross-sectional area S (mm^2) of the conductor **3** on the horizontal axis and the compression interval L (mm) of the conductor **3** on the vertical axis. Here, the inventors found the compression width W (mm) and the compression interval L (mm) that meet both the target specifications that **(1)** the electric resistance ratio R**2** after the high-temperature environmental exposure test is **100**% or less, and **(2)** the resistance ratio-increase rate should be **20**% or less, under conditions where the cross-sectional area of the conductor **3** is **38** mm^2 or more and **500** mm^2 or less. As a result, it was found that when the compression width W (mm) meets the following formula **(3),** and the compression interval L (mm) meets the following formula **(4),** both the target specifications that **(1)** the electric resistance ratio R**2** after the high-temperature environmental exposure test is **100**% or less, and **(2)** the resistance ratio-increase rate should be **20**% or less would be satisfied:

$$0.01 \times S + 2.5 \leq W \leq 0.035 \times S + 4.25 \cdot \cdot \cdot (3),$$

and

$$-1.0 \leq L \leq 0.09 \times S + 4.5 \cdot \cdot \cdot (4).$$

[0052] The region expressed by the formula **(3)** is shown as a hatched area in **FIG. 9**A. Similarly, the region expressed by the formula **(4)** is shown as a hatched area in **FIG. 9**B. For example, when the cross-sectional area S of the conductor **3** is **50** mm^2, it is possible to select the compression width W to be **3** mm or more and **6** mm or less, and the compression interval L to be -**1** mm or more and **9** mm or less. By using the compression width W and the compression interval L in the above regions, it is possible to achieve that the electric resistance ratio R**2** after the high-temperature environmental exposure test would be not more than **100**% and the resistance ratio-increase rate is **20**% or less.

[0053] From the above results, by adjusting the compression width W and the compression interval L to meet the formulas **(1)** and **(2)** to form the compressed portions **10,** it is possible to provide the electric wire with terminal **1** which has a lower electric resistance ratio R**2** after the high-temperature environmental exposure test, and which meets the target specifications above. In addition, by adjusting the compression width W and the compression interval L to meet the formulas **(3)** and **(4)** to form the compressed portions **10,** it is possible to provide the electric wire with terminal **1** which has a lower electric resistance ratio R**2** and a low resistance ratio-increase rate after the high-temperature environmental exposure test, and which meets the target specifications as described above.

[0054] In other words, the electric wire with terminal **1** according to the present embodiment is expressed by the formulas **(1)** and **(2)** that define the relationship of the compression width W (mm) and the compression interval L (mm) with respect to the cross-sectional area S (mm^2) of the conductor **3:**

$$0.01 \times S + 2.5 \leq W \leq 0.07 \times S + 3.5 \cdots (1),$$

and

$$-1.0 \leq L \leq 0.145 \times S + 3.75 \cdots (2).$$

[0055] Even within this range, the resistance ratio-increase rate may be more than **20**% depending on the compression width W and the compression interval L. For satisfying both the formulas **(1)** and **(2)** of the above target specifications, the compression width W (mm) and the compression interval L (mm) preferably meets the following formulas **(3), (4)** of the conductor cross-sectional area S (mm^2):

$$0.01 \times S + 2.5 \leq W \leq 0.035 \times S + 4.25 \cdots (3),$$

and

$$-1.0 \leq L \leq 0.09 \times S + 4.5 \cdots (4).$$

[0056] For example, if the outer diameter of the conductor **3** is small, setting the compression width W too small may result in the target specification not being met. The cross-sectional area S of the conductor **3,** for example, should be **38** mm^2 or more and **500** mm^2 or less.

(Functions and effects of the embodiment)

[0057] As explained above, in the electric wire with terminal **1** in the present embodiment, the tensile strength of the material used for the conductor **3** is greater than the tensile strength of the material used for the terminal **5,** and the terminal **5** has three or more compressed portions **10** in the longitudinal direction of the conductor **3,** wherein the cross-sectional area of the conductor **3** is S (mm^2), the compression width which is the length in the longitudinal direction of the compressed portion **10** is W (mm), and the compression interval which is the length in the longitudinal direction of the non-compressed portion **11** located between the adjacent compressed portions **10** is L (mm), wherein the compression width W (mm) and the compression interval L (mm), respectively, satisfy the formulas **(1)** and **(2):**

$$0.01 \times S + 2.5 \leq W \leq 0.07 \times S + 3.5 \cdots (1),$$

and

$$-1.0 \leq L \leq 0.145 \times S + 3.75 \cdots (2).$$

[0058] More preferably, the compression width W (mm) and the compression interval L (mm) satisfy the following formulas **(3)** and **(4):**

$$0.01 \times S+2.5 \leq W \leq 0.035 \times S+4.25 \cdots (3),$$

and

$$-1.0 \leq L \leq 0.09 \times S + 4.5 \cdots (4).$$

[0059] According to the above configuration, it is possible to increase the contact force (axial contact force) between the conductor **3** and the terminal **5,** regardless of the size (the outer diameter or the conductor cross-sectional area) of the conductor **3,** thereby maintain a low electric resistance between the conductor **3** and the terminal **5.** Thus, it is possible to achieve the electric wire with terminal 1 which provides sufficient electrical connectivity.

(Summary of the embodiment)

[0060] Next, the technical ideas grasped from the embodiments will be described with the aid of the reference characters and the like in the embodiments. It should be noted, however, that each of the reference characters and the like in the following descriptions is not to be construed as limiting the constituent elements in the appended claims to the members and the like specifically shown in the embodiments.

[1] An electric wire with terminal **(1),** comprising:

an electric wire **(2)** including a conductor **(3)** and an insulating layer **(4)** covering the conductor **(3);** and
a terminal **(5)** including a hollow portion **(7)** into which the conductor **(3)** exposed at an end portion of the electric wire **(2)** is inserted,
wherein the terminal **(5)** is connected to the conductor **(3)** by compressing the hollow portion **(7)** with the conductor **(3)** being inserted into the hollow portion **(7),**
wherein a tensile strength of a material used for the conductor **(3)** is greater than a tensile strength of a material used for the terminal **(5),**
wherein the terminal **(5)** includes at least three compressed portions **(10)** in a longitudinal direction of the conductor **(3),**
wherein a cross-sectional area of the conductor **(3)** is S (mm^2), a compression width which is a length in the longitudinal direction of the compressed portion **(10)** is W (mm), and a compression interval which is a length in the longitudinal direction of the non-compressed portion **(11)** located between adjacent compressed portions **(10)** is L (mm), wherein the compression width W and the compression interval L, respectively, satisfy formulas **(1)** and **(2):**

$$0.01 \times S+2.5 \leq W \leq 0.07 \times S+3.5 \cdots (1),$$

and

$$-1.0 \leq L \leq 0.145 \times S + 3.75 \cdots (2).$$

[2] The electric wire with terminal **1** as described in **[1],** wherein the compression width W and the compression interval L satisfy formulas **(3)** and **(4):**

$$0.01 \times S+2.5 \leq W \leq 0.035 \times S+4.25 \cdots (3),$$

and

$$-1.0 \leq L \leq 0.09 \times S + 4.5 \cdot \cdot \cdot (4).$$

[3] The electric wire with terminal **(1)** as described in **[1]** or **[2]**, wherein the terminal **(5)** comprises an aluminum material, and the conductor **(3)** comprises an aluminum material with a greater tensile strength than a tensile strength of the aluminum material used for the terminal **(5)**.

[4] A method for manufacturing an electric wire with terminal **(1)** comprising an electric wire **(2)** including a conductor **(3)** and an insulating layer **(4)** covering the conductor **(3)**, and a terminal **(5)** including a hollow portion **(7)** into which the conductor **(3)** exposed at an end portion of the electric wire **(2)** is inserted, wherein the terminal **(5)** is connected to the conductor **(3)** by compressing the hollow portion **(7)** with the conductor **(3)** being inserted into the hollow portion **(7)**,
the method comprising:

preparing the electric wire **(2)** and the terminal **(5)**, wherein a tensile strength of a material used for the conductor **(3)** is greater than a tensile strength of a material used for the terminal **(5)**; and
connecting the terminal **(5)** to the conductor **(3)** by compressing the terminal **(5)** with the conductor **(3)**, exposed at the end portion of the electric wire **(2)**, being inserted in the hollow portion **(7)** at least three times, to form at least three compressed portions **(10)** at the terminal **(5)**,
wherein the at least three compressed portions **(10)** are formed by forming adjacent compressed portions **(10)** and thereafter forming an other compressed portion **(10)** between the adjacent compressed portions **(10)**,
wherein the compressed portion is formed in such a manner than a cross-sectional area of the conductor **(3)** is S (mm^2), a compression width which is a length in the longitudinal direction of the compressed portion **(10)** is W (mm), and a compression interval which is a length in the longitudinal direction of the non-compressed portion **(11)** located between adjacent compressed portions **(10)** is L (mm), wherein the compression width W and the compression interval L, respectively, satisfy formulas **(1)** and **(2)**:

$$0.01 \times S + 2.5 \leq W \leq 0.07 \times S + 3.5 \cdot \cdot \cdot (1),$$

and

$$-1.0 \leq L \leq 0.145 \times S + 3.75 \cdot \cdot \cdot (2).$$

[5] The method as described in **[4]**, wherein the compression width W and the compression interval L satisfy formulas **(3)** and **(4)**:

$$0.01 \times S + 2.5 \leq W \leq 0.035 \times S + 4.25 \cdot \cdot \cdot (3),$$

and

$$-1.0 \leq L \leq 0.09 \times S + 4.5 \cdot \cdot \cdot (4).$$

[0061] Although the embodiments of the present invention have been described above, the embodiments are not to be construed as limiting the inventions according to the appended claims. Further, it should be noted that not all the combinations of the features described in the embodiments are indispensable to the means for solving the problem of the invention. Further, the present invention can appropriately be modified and implemented without departing from the spirit of the present invention.

Claims

1. An electric wire with terminal **(1)**, comprising:

an electric wire **(2)** including a conductor **(3)** and an insulating layer **(4)** covering the conductor **(3)**; and
a terminal **(5)** including a hollow portion **(7)** into which the conductor **(3)** exposed at an end portion of the electric

wire **(2)** is inserted,
wherein the terminal **(5)** is connected to the conductor **(3)** by compressing the hollow portion **(7)** with the conductor **(3)** being inserted into the hollow portion **(7),**
wherein a tensile strength of a material used for the conductor **(3)** is greater than a tensile strength of a material used for the terminal **(5),**
wherein the terminal **(5)** includes at least three compressed portions **(10)** in a longitudinal direction of the conductor **(3),**
wherein a cross-sectional area of the conductor **(3)** is S (mm^2), a compression width which is a length in the longitudinal direction of the compressed portion **(10)** is W (mm), and a compression interval which is a length in the longitudinal direction of a non-compressed portion **(11)** located between adjacent compressed portions **(10)** is L (mm), wherein the compression width W and the compression interval L, respectively, satisfy formulas **(1)** and **(2):**

$$0.01 \times S+2.5 \leq W \leq 0.07 \times S+3.5 \cdots (1),$$

and

$$-1.0 \leq L \leq 0.145 \times S + 3.75 \cdots (2).$$

2. The electric wire with terminal 1 according to claim **1,** wherein the compression width W and the compression interval L satisfy formulas **(3)** and **(4):**

$$0.01 \times S+2.5 \leq W \leq 0.035 \times S+4.25 \cdots (3),$$

and

$$-1.0 \leq L \leq 0.09 \times S + 4.5 \cdots (4).$$

3. The electric wire with terminal **(1)** according to claim **1** or **2,** wherein the terminal **(5)** comprises an aluminum material, and the conductor **(3)** comprises an aluminum material with a greater tensile strength than a tensile strength of the aluminum material used for the terminal **(5).**

4. A method for manufacturing an electric wire with terminal **(1)** comprising an electric wire **(2)** including a conductor **(3)** and an insulating layer **(4)** covering the conductor **(3),** and a terminal **(5)** including a hollow portion **(7)** into which the conductor **(3)** exposed at an end portion of the electric wire **(2)** is inserted, wherein the terminal **(5)** is connected to the conductor **(3)** by compressing the hollow portion **(7)** with the conductor **(3)** being inserted into the hollow portion **(7),**
the method comprising:

preparing the electric wire **(2)** and the terminal **(5),** wherein a tensile strength of a material used for the conductor **(3)** is greater than a tensile strength of a material used for the terminal **(5);** and
connecting the terminal **(5)** to the conductor **(3)** by compressing the terminal **(5)** with the conductor **(3)** being inserted in the hollow portion **(7)** at least three times, to form at least three compressed portions **(10)** at the terminal **(5),**
wherein the at least three compressed portions **(10)** are formed by forming adjacent compressed portions **(10)** and thereafter forming an other compressed portion **(10)** between the adjacent compressed portions **(10),**
wherein the compressed portion is formed in such a manner than a cross-sectional area of the conductor **(3)** is S (mm^2), a compression width which is a length in a longitudinal direction of the compressed portion **(10)** is W (mm), and a compression interval which is a length in the longitudinal direction of a non-compressed portion **(11)** located between adjacent compressed portions **(10)** is L (mm), wherein the compression width W and the compression interval L, respectively, satisfy formulas **(1)** and **(2):**

$$0.01 \times S+2.5 \leq W \leq 0.07 \times S+3.5 \cdots (1),$$

and

$$-1.0 \leq L \leq 0.145 \times S + 3.75 \cdots (2).$$

5. The method according to claim **4,** wherein the compression width W and the compression interval L satisfy formulas **(3)** and **(4):**

$$0.01 \times S + 2.5 \leq W \leq 0.035 \times S + 4.25 \cdots (3),$$

and

$$-1.0 \leq L \leq 0.09 \times S + 4.5 \cdots (4).$$

FIG. 1A

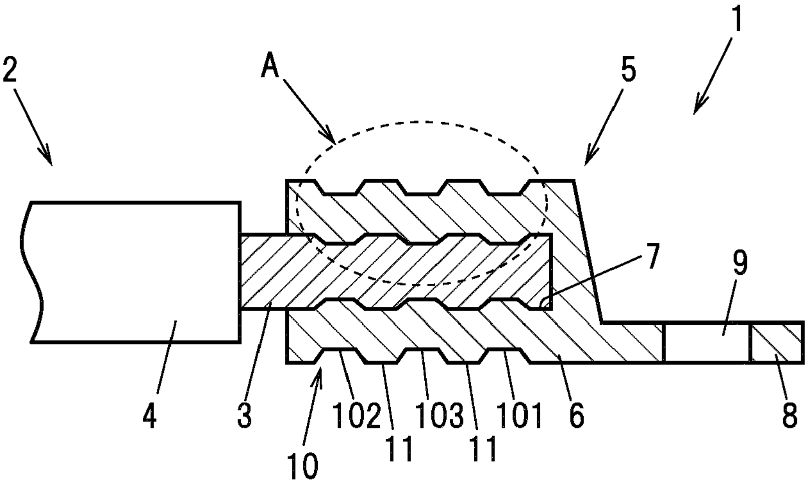


FIG. 1B

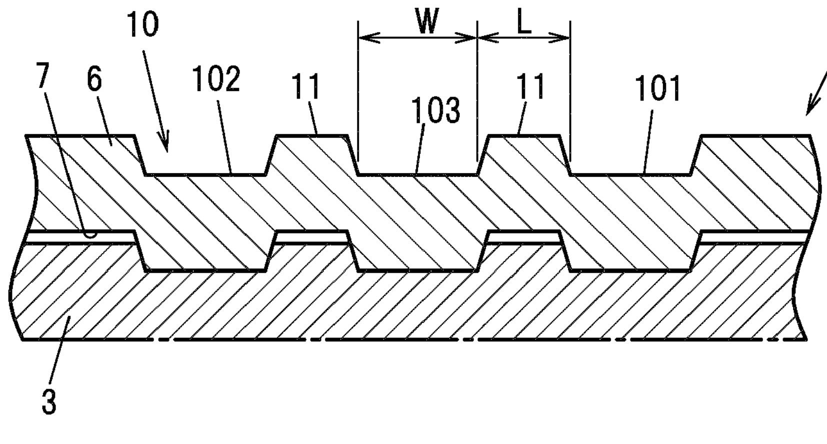


FIG. 2A

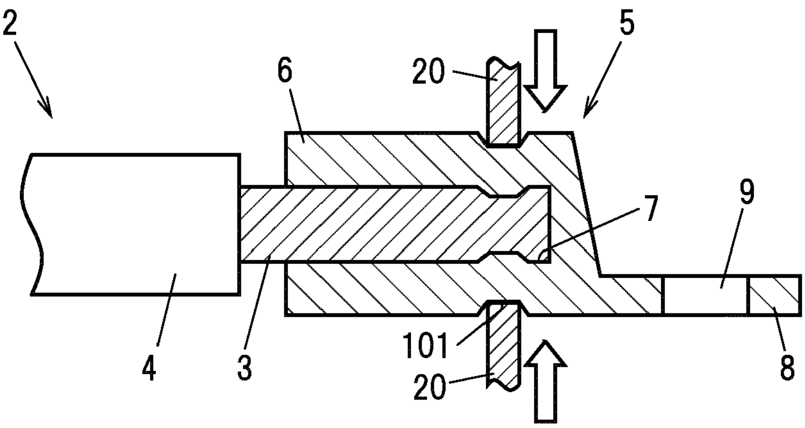


FIG. 2B

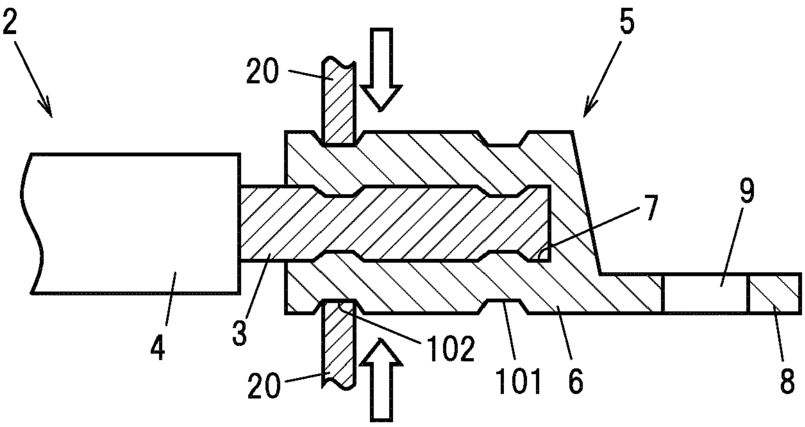


FIG. 2C

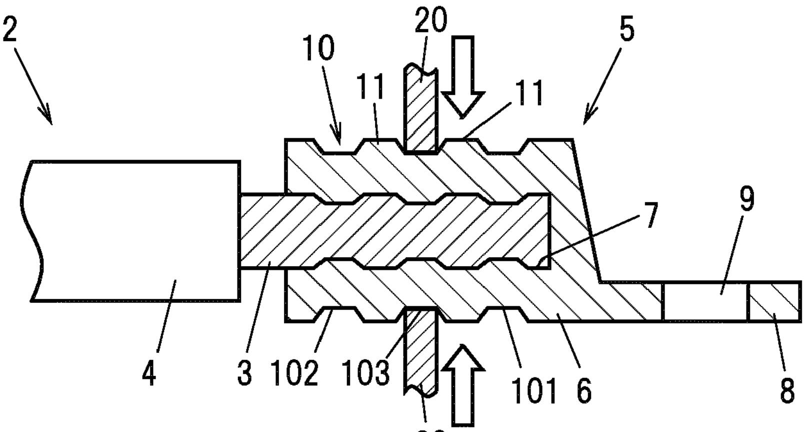


FIG. 3A

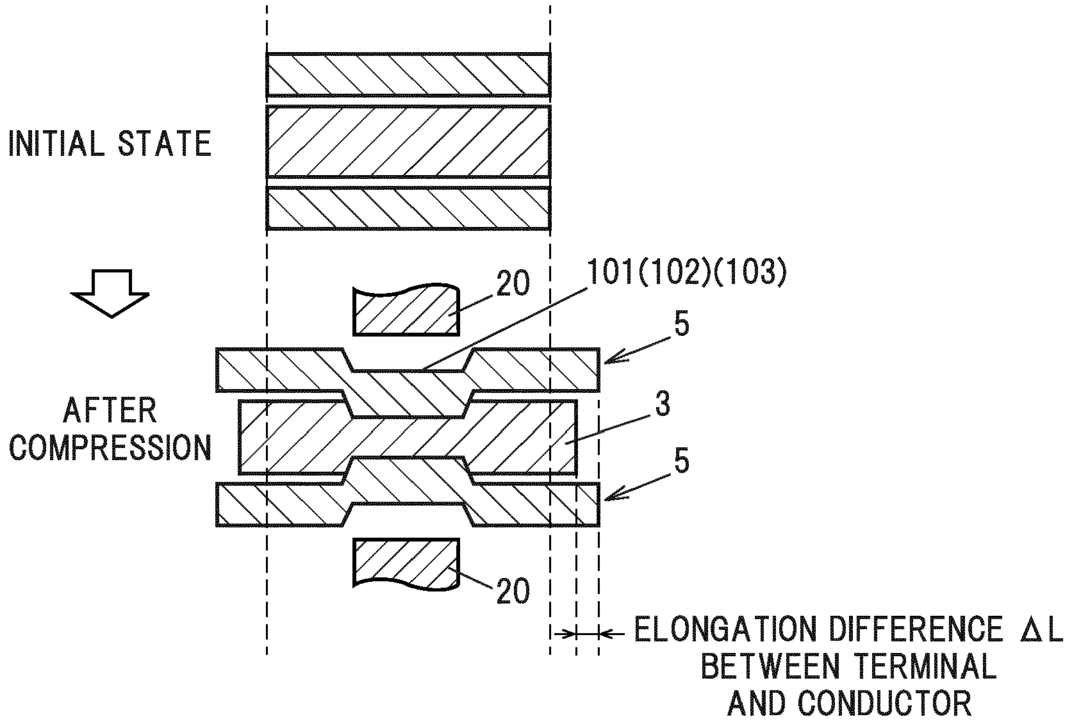

INITIAL STATE
AFTER COMPRESSION
20
101(102)(103)
5
3
5
20
ELONGATION DIFFERENCE ΔL BETWEEN TERMINAL AND CONDUCTOR

FIG. 3B

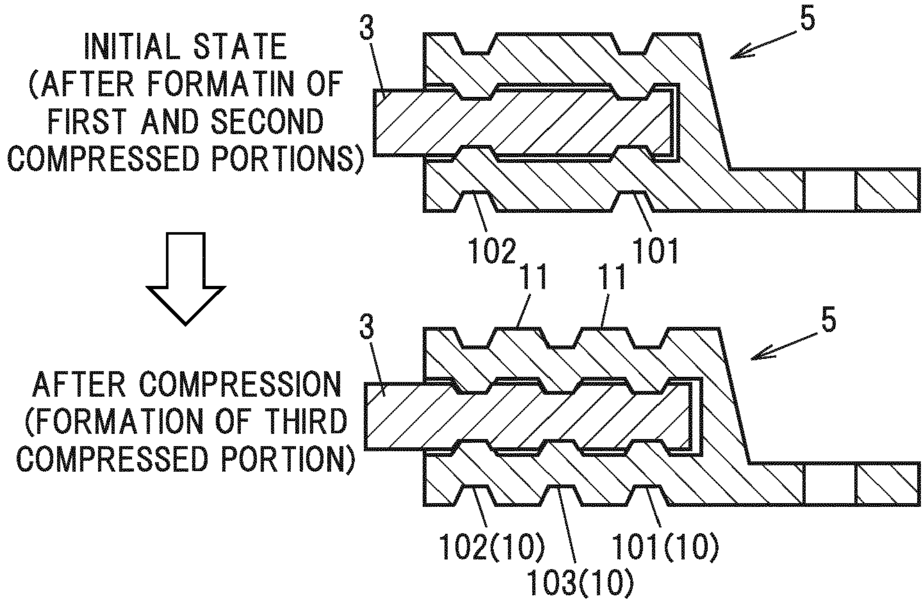

INITIAL STATE (AFTER FORMATIN OF FIRST AND SECOND COMPRESSED PORTIONS)
3
5
102
101
11
11
3
5
AFTER COMPRESSION (FORMATION OF THIRD COMPRESSED PORTION)
102(10)
101(10)
103(10)

FIG. 4

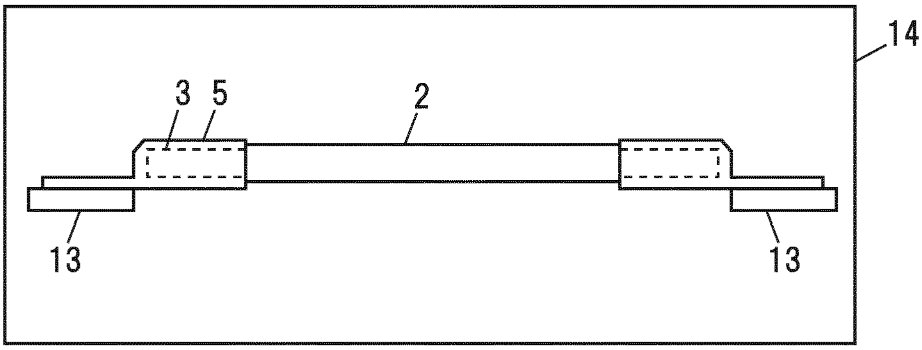


FIG. 5

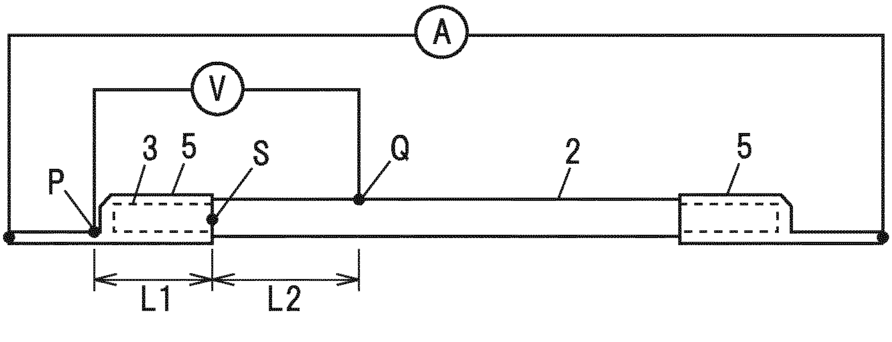


FIG. 6A

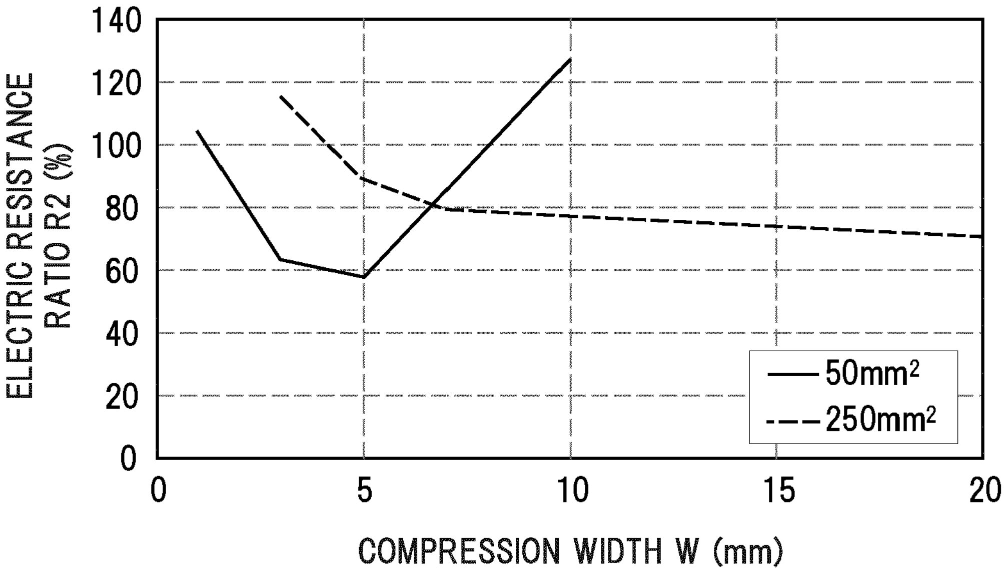

ELECTRIC RESISTANCE RATIO R2 (%)
140
120
100
80
60
40
20
0
0
5
10
15
20
COMPRESSION WIDTH W (mm)
50mm2
250mm2

FIG. 6B

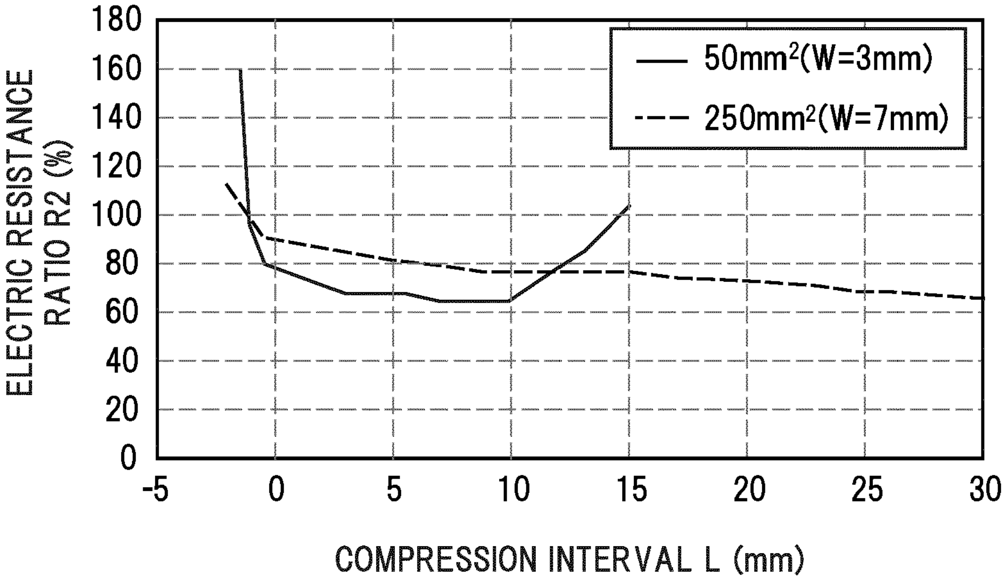

ELECTRIC RESISTANCE RATIO R2 (%)
180
160
140
120
100
80
60
40
20
0
-5
0
5
10
15
20
25
30
COMPRESSION INTERVAL L (mm)
50mm2(W=3mm)
250mm2(W=7mm)

FIG. 6C

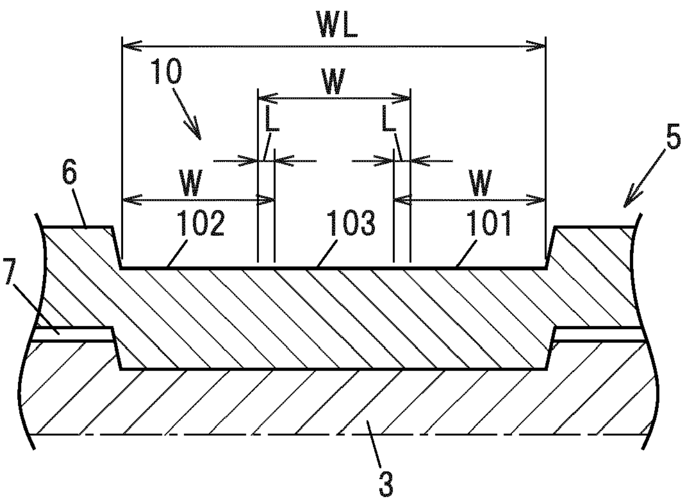


FIG.7A

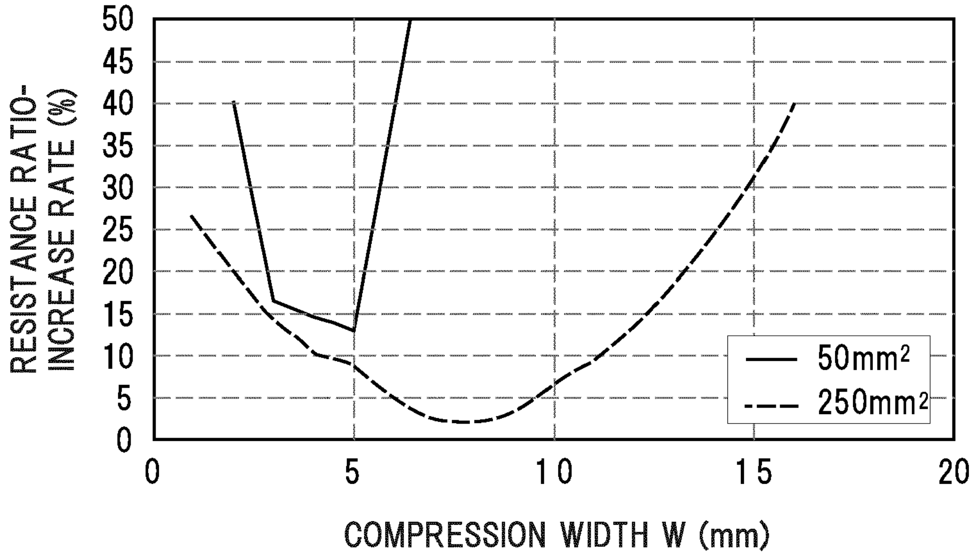

RESISTANCE RATIO-INCREASE RATE (%)
50
45
40
35
30
25
20
15
10
5
0
0
5
10
15
20
COMPRESSION WIDTH W (mm)
50mm2
250mm2

FIG.7B

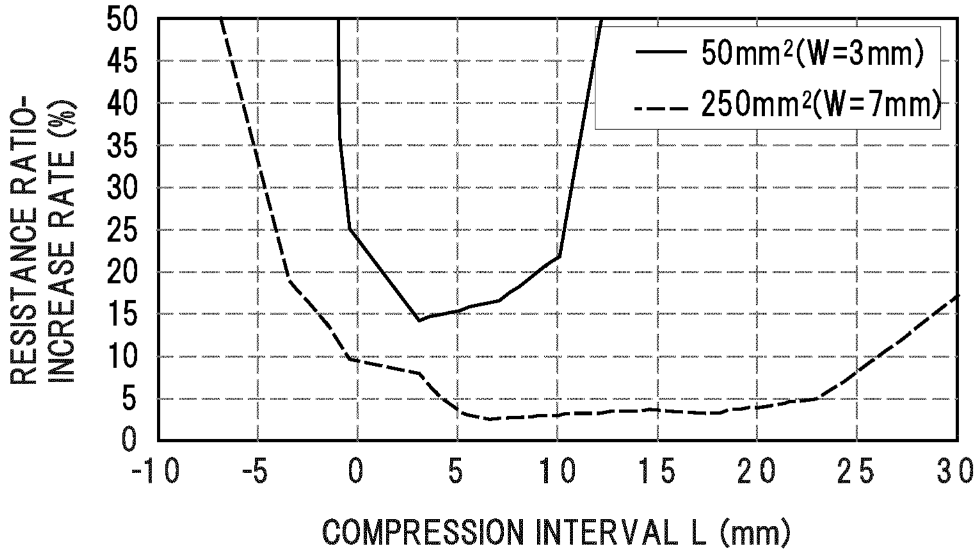

RESISTANCE RATIO-INCREASE RATE (%)
50
45
40
35
30
25
20
15
10
5
0
-10
-5
0
5
10
15
20
25
30
COMPRESSION INTERVAL L (mm)
50mm2(W=3mm)
250mm2(W=7mm)

FIG. 8A

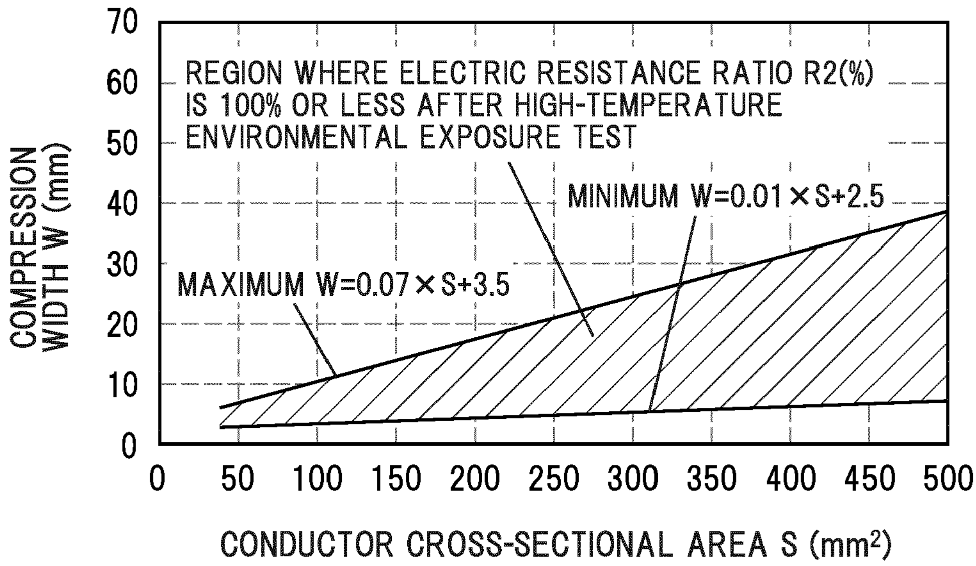

REGION WHERE ELECTRIC RESISTANCE RATIO R2(%) IS 100% OR LESS AFTER HIGH-TEMPERATURE ENVIRONMENTAL EXPOSURE TEST
MINIMUM W=0.01×S+2.5
MAXIMUM W=0.07×S+3.5
COMPRESSION WIDTH W (mm)
CONDUCTOR CROSS-SECTIONAL AREA S (mm2)
70
60
50
40
30
20
10
0
0
50
100
150
200
250
300
350
400
450
500

FIG. 8B

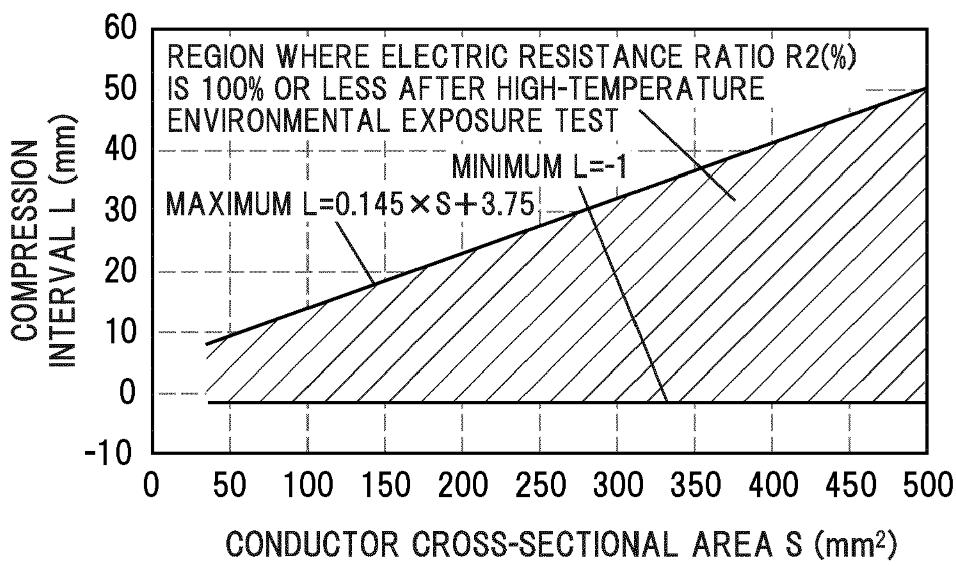

REGION WHERE ELECTRIC RESISTANCE RATIO R2(%) IS 100% OR LESS AFTER HIGH-TEMPERATURE ENVIRONMENTAL EXPOSURE TEST
MINIMUM L=-1
MAXIMUM L=0.145×S+3.75
COMPRESSION INTERVAL L (mm)
CONDUCTOR CROSS-SECTIONAL AREA S (mm2)
60
50
40
30
20
10
0
-10
0
50
100
150
200
250
300
350
400
450
500

FIG. 9A

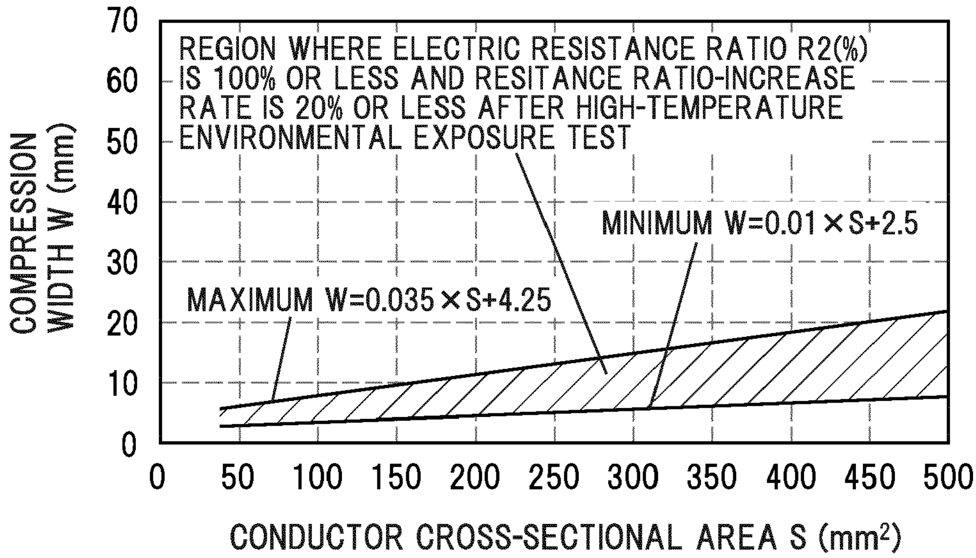
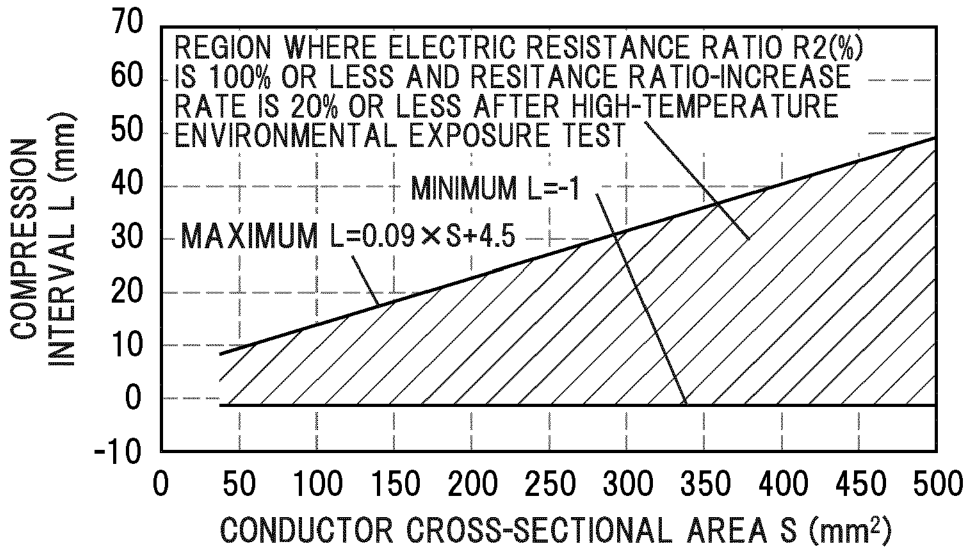

70
60
50
40
30
20
10
0
COMPRESSION WIDTH W (mm)
REGION WHERE ELECTRIC RESISTANCE RATIO R2(%) IS 100% OR LESS AND RESITANCE RATIO-INCREASE RATE IS 20% OR LESS AFTER HIGH-TEMPERATURE ENVIRONMENTAL EXPOSURE TEST
MINIMUM W=0.01×S+2.5
MAXIMUM W=0.035×S+4.25
0 50 100 150 200 250 300 350 400 450 500
CONDUCTOR CROSS-SECTIONAL AREA S (mm2)

FIG. 9B


70
60
50
40
30
20
10
0
-10
COMPRESSION INTERVAL L (mm)
REGION WHERE ELECTRIC RESISTANCE RATIO R2(%) IS 100% OR LESS AND RESITANCE RATIO-INCREASE RATE IS 20% OR LESS AFTER HIGH-TEMPERATURE ENVIRONMENTAL EXPOSURE TEST
MINIMUM L=-1
MAXIMUM L=0.09×S+4.5
0 50 100 150 200 250 300 350 400 450 500
CONDUCTOR CROSS-SECTIONAL AREA S (mm2)

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EUROPEAN SEARCH REPORT

Application Number
EP 21 18 4373

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	JP 4 976230 B2 (SANEISHA SEISAKUSHO KK) 18 July 2012 (2012-07-18) * paragraph [0001] - paragraph [0032]; figure 1 * -----	1-5	INV. H01R43/048
X,P	EP 3 687 000 A1 (HITACHI METALS LTD [JP]) 29 July 2020 (2020-07-29) * paragraph [0001] - paragraph [0082]; figures 1, 3C * -----	1-5	
			TECHNICAL FIELDS SEARCHED (IPC)
			H01R

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	18 November 2021	Mateo Segura, C

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18-11-2021

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JP 4976230 B2	18-07-2012	JP 4976230 B2	18-07-2012
		JP 2009037952 A	19-02-2009
EP 3687000 A1	29-07-2020	CN 111490362 A	04-08-2020
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Patent documents cited in the description

- JP 2020119682 A **[0001]**
- WO 9854790 A **[0004] [0005]**