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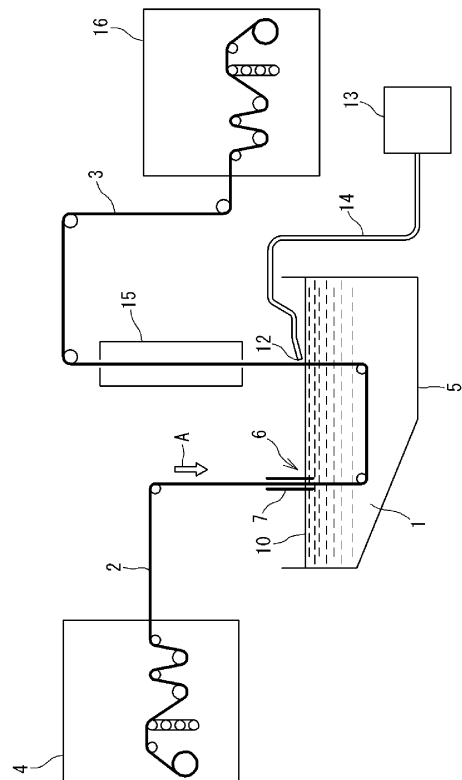
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(54) **PRODUCTION METHOD FOR MOLTEN-ALUMINUM-PLATED COPPER WIRE**

(57) A production method for molten-aluminum-plated steel wire, the production method being characterized in that a steel wire (2) immersion part (6) at which the steel wire (2) is to be immersed in a molten aluminum plating bath (1) is immersed in the molten aluminum plating bath (1) after the steel wire (2) has been passed into a steel wire introduction device (7) while an immersion region (9a) thereof has been immersed in the molten aluminum plating bath (1). The steel wire introduction device (7) comprises a tube-shaped body (9), which has a total length of 10 to 1000 mm and has a through hole (8) that is for passing the steel wire (2) through the inside thereof, and includes the immersion region (9a), which is for immersion in the molten aluminum plating bath (1) to a length of 2 mm to 400 mm from an end part of one end of the tube-shaped body (9) along the long direction of the tube-shaped body (9). The ratio of the area of the opening of the through hole (8) and the area of a horizontal cross-section of the steel wire (2) (the area of the opening of the through-hole (8) of the tube-shaped body (9)/the area of the horizontal cross-section of the steel wire (2)) is 3 to 4000.

[Fig. 1]



Description

TECHNICAL FIELD

[0001] The present invention relates to a method for producing a hot-dip aluminum-coated steel wire. More particularly, the present invention relate to a method for producing a hot-dip aluminum-coated steel wire which can be suitably used in, for example, a wire harness of an automobile, and the like, and a steel wire-introducing device for hot-dip aluminum plating, which can be suitably used in the method for producing a hot-dip aluminum-coated steel wire.

[0002] In the present description, the hot-dip aluminum-coated steel wire means a steel wire which has been plated with aluminum by dipping a steel wire in molten aluminum, and then continuously drawing up the steel wire from the molten aluminum. In addition, the molten aluminum means a plating liquid of molten aluminum.

BACKGROUND ART

[0003] A copper wire has been hitherto used as an electric wire which is used in a wire harness of an automobile, and the like. As an electric wire having a light weight without impairing electric conductivity in place of the copper wire, it has been desired in recent years to develop a composite electric wire made of a strand of an aluminum wire having a weight lighter than the copper wire and a metal wire having strength higher than the aluminum wire. As a metal wire having strength higher than the aluminum wire, a hot-dip Al-coated steel wire obtained by plating a steel wire with hot-dip aluminum has been proposed (for example, see claim 1 and paragraph [0004] of Patent Literature 1).

[0004] The above-mentioned hot-dip Al-coated steel wire has been produced by dipping a steel wire or a steel wire having a zinc plated layer or a nickel plated layer on its surface as a starting wire in molten aluminum, and then continuously drawing up the steel wire from the molten aluminum to the air (see, for example, paragraph [0024] of Patent Literature 1).

PRIOR ART LITERATURES

PATENT LITERATURES

[0005] Patent Literature 1: Japanese Patent Unexamined Publication No. 2014-185355

SUMMARY OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0006] According to the above-mentioned process, when the starting wire is the steel wire or the steel wire having a nickel plated layer on its surface, there is a possibility that an obtained hot-dip aluminum-coated steel wire has an area where a plating film is not formed on its surface after dipping the steel wire in molten aluminum, and then continuously drawing up the steel wire from the molten aluminum to the air.

[0007] The present invention has been made in view of the above-mentioned prior art. An object of the present invention is to provide a method for efficiently producing a hot-dip aluminum-coated steel wire having a plating film over the whole surface, and a steel wire-introducing device for hot-dip aluminum plating, which can be suitably used in the method for producing a hot-dip aluminum-coated steel wire.

MEANS FOR SOLVING THE PROBLEMS

[0008] The present invention relates to:

(1) a method for producing a hot-dip aluminum-coated steel wire by dipping a steel wire in molten aluminum, and then continuously drawing up the steel wire from the molten aluminum, to produce a hot-dip aluminum-coated steel wire, which includes:

introducing a steel wire into a steel wire-introducing device including a tubular body of 10 mm to 1000 mm in total length having a through hole for introducing a steel wire into the tubular body, and a dipping region of 2 mm to 400 mm in length from one end part of the tubular body in a longitudinal direction of the tubular body for dipping the dipping region in the molten aluminum, wherein a value of the ratio of an area of the opening part of the through hole to an area of the cross section of the steel wire which is used in hot-dip aluminum plating [area of the opening part of the through hole of the tubular body/area of the cross section of the steel wire] is 3 to 4000, under a condition that the dipping region of the steel wire-introducing device is dipped in the molten

aluminum, and thereafter
dipping the steel wire in the molten aluminum;

(2) the method for producing a hot-dip aluminum-coated steel wire according to the above item (1), wherein the steel wire is a steel wire made of stainless steel or carbon steel; and

(3) a steel wire-introducing device used in a dipping area of a steel wire where the steel wire is dipped in molten aluminum when a hot-dip aluminum-coated steel wire is produced by dipping the steel wire in the molten aluminum, and then continuously drawing up the steel wire from the molten aluminum, which includes a tubular body of 10 mm to 1000 mm in total length having a through hole for introducing a steel wire into the tubular body, and a dipping region of 2 mm to 400 mm in length from one end part of the tubular body in a longitudinal direction of the tubular body for dipping the dipping region in the molten aluminum, wherein a value of the ratio of an area of the opening part of the through hole to an area of the cross section of the steel wire which is used in hot-dip aluminum plating [area of the opening part of the through hole of the tubular body/area of the cross section of the steel wire] is 3 to 4000.

EFFECTS OF THE INVENTION

[0009] According to the method for producing a hot-dip aluminum-coated steel wire and the steel wire-introducing device of the present invention, excellent effects such that a hot-dip aluminum-coated steel wire having a plating film over the whole surface can be efficiently produced are exhibited.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010]

Fig. 1 is a schematic view showing one embodiment of a method for producing a hot-dip aluminum-coated steel wire according to the present invention.

Fig. 2 is a schematic cross-sectional view showing one embodiment of a steel wire-introducing device for hot-dip aluminum plating according to the present invention.

Fig. 3 is a schematic explanatory view showing another embodiment of the method for producing hot-dip aluminum-coated steel wire according to the present invention.

Fig. 4 is a schematic explanatory view showing a boundary portion between a steel wire and a surface of molten aluminum when the steel wire is drawn up from the molten aluminum in the method for producing a hot-dip aluminum-coated steel wire according to the present invention.

Fig. 5 is a schematic explanatory view showing one embodiment of a method for determining an average thickness of a plating film of a hot-dip aluminum-coated steel wire obtained in each of working examples and comparative examples.

MODE FOR CARRYING OUT THE INVENTION

[0011] The method for producing a hot-dip aluminum-coated steel wire of the present invention includes a process for dipping a steel wire in molten aluminum, and then continuously drawing up the steel wire from the molten aluminum, to produce a hot-dip aluminum-coated steel wire. The method includes one of characteristics in introducing a steel wire into a steel wire-introducing device including a tubular body of 10 mm to 1000 mm in total length having a through hole for introducing a steel wire into the tubular body, and a dipping region of 2 mm to 400 mm in length from one end part of the tubular body in a longitudinal direction of the tubular body for dipping the dipping region in the molten aluminum, wherein a value of the ratio of an area of the opening part of the through hole to an area of the cross section of the steel wire which is used in hot-dip aluminum plating [area of the opening part of the through hole of the tubular body/area of the cross section of the steel wire] is 3 to 4000, under a condition that the dipping region of the steel wire-introducing device is dipped in the molten aluminum; and thereafter dipping the steel wire in the molten aluminum, as mentioned above.

[0012] According to the method for producing a hot-dip aluminum-coated steel wire of the present invention, a hot-dip aluminum-coated steel wire having a plating film over the whole surface can be efficiently produced since the above-mentioned processes are employed in the method.

[0013] In addition, when a hot-dip aluminum-coated steel wire is produced by using the steel wire-introducing device of the present invention, it is inhibited that an oxide film generated on the surface of the molten aluminum is included in the molten aluminum together with the steel wire at a place where the steel wire is introduced from the air to the molten aluminum. Thereby reactivity of the steel wire with the molten aluminum can be improved, and therefore generation of an area where a plating film is not formed on the surface of the hot-dip aluminum-coated steel wire can be suppressed.

[0014] Hereinafter, the method for producing a hot-dip aluminum-coated steel wire according to the present invention will be described based on drawings. However, the present invention is not limited only to those embodiments described in the drawings.

[0015] Fig. 1 is a schematic explanatory view showing one embodiment of the method for producing a hot-dip aluminum-coated steel wire according to the present invention.

[0016] According to the method for producing a hot-dip aluminum-coated steel wire of the present invention, a steel wire 2 is dipped in molten aluminum 1, and then the steel wire 2 is continuously drawn up from the molten aluminum 1, to produce a hot-dip aluminum-coated steel wire 3.

[0017] Examples of steel used in the steel wire 2 include, for example, stainless steel, carbon steel and the like, and the present invention is not limited only to those exemplified ones.

[0018] The stainless steel is an alloy steel containing 10% by mass or more of chromium (Cr). Examples of the stainless steel include, for example, austenitic steel materials, ferritic steel materials and martensitic steel materials defined in JIS G4309, and the like, and the present invention is not limited only to those exemplified ones. Specific examples of the stainless steel include stainless steel in which an austenitic phase is generally considered to be metastable, such as SUS301 and SUS304; stable austenitic stainless steel such as SUS305, SUS310 and SUS316; ferritic stainless steel such as SUS405, SUS410L, SUS429, SUS430, SUS434, SUS436, SUS444 and SUS447; martensitic stainless steel such as SUS403, SUS410, SUS416, SUS420, SUS431 and SUS440; chromium-nickel-manganese-based stainless steel classified into SUS200 series, and the like, and the present invention is not limited only to those exemplified ones.

[0019] The carbon steel contains 0.02% by mass or more of carbon (C). Examples of the carbon steel include, for example, high carbon steel wire rods defined in JIS G3506, low carbon steel wire rods defined in JIS G3505, and the like, and the present invention is not limited only to those exemplified ones. Specific examples of the carbon steel include high carbon steel, low carbon steel and the like, and the present invention is not limited only to those exemplified ones.

[0020] Among the above-mentioned steels, the stainless steel and the carbon steel are preferred, and the stainless steel is more preferred, from the viewpoint of increase in tensile strength of the hot-dip aluminum-coated steel wire 3.

[0021] The diameter of the steel wire 2 is not particularly limited. It is preferred that the diameter of the steel wire 2 is appropriately controlled in accordance with uses of the hot-dip aluminum-coated steel wire 3. For example, when the hot-dip aluminum-coated steel wire 3 is used in a wire harness of an automobile and the like, it is preferred that the diameter of the steel wire 2 is usually 0.05 to 0.5 mm or so.

[0022] The steel wire 2 can be previously degreased before carrying out hot-dip aluminum plating of the steel wire 2. The degreasing of the steel wire 2 can be carried out by, for example, a method which includes dipping the steel wire 2 in an alkaline degreasing liquid, taking out the steel wire 2 from the alkaline degreasing liquid, neutralizing the alkaline degreasing liquid deposited on the steel wire 2, and washing the steel wire 2 with water; a method which includes carrying out electrolytic degreasing of the steel wire 2 by passing electricity through the steel wire 2 under a condition such that the steel wire 2 is dipped in an alkaline degreasing liquid; and the like. Incidentally, the above-mentioned alkaline degreasing liquid may contain a surfactant from the viewpoint of improvement in degreasing property.

[0023] A plating film (not shown in the figure) made of aluminum or an aluminum alloy has been formed on the surface of the hot-dip aluminum-coated steel wire 3. In the present invention, since the plating film made of aluminum or an aluminum alloy has been formed on the surface of the hot-dip aluminum-coated steel wire 3 as mentioned above, the hot-dip aluminum-coated steel wire 3 is excellent in adhesiveness to an aluminum wire when a wire harness is produced by bundling the hot-dip aluminum-coated steel wire 3 with the aluminum wire, and tensile strength and temporal stability of electric resistance.

[0024] In Fig. 1, the steel wire 2 is provided from a delivery device 4 of the steel wire 2. Thereafter, the steel wire 2 is continuously transferred in the direction of arrow A, and dipped in the molten aluminum 1 charged in a plating bath 5.

[0025] Incidentally, when the steel wire 2 is made of carbon steel, it is preferred that degreasing of the steel wire 2 is carried out between the delivery device 4 and the molten aluminum 1, because there is a possibility that rust is generated on the surface of the steel wire 2 due to degreasing of the steel wire 2 until hot-dip aluminum plating of the steel wire 2 is carried out. The degreasing of the steel wire 2 made of carbon steel can be carried out in the same manner as the above-mentioned method for degreasing the steel wire 2.

[0026] The molten aluminum 1 may contain only aluminum. Alternatively, the molten aluminum 1 may contain an element other than aluminum as occasion demands within a scope which would not hinder an object of the present invention. Examples of the element other than aluminum include, for example, nickel, chromium, zinc, silicon, copper, iron and the like, and the present invention is not limited only to those exemplified ones. When the element other than aluminum is contained in aluminum, mechanical strength of a plating film can be increased, and moreover, tensile strength of the hot-dip aluminum-coated steel wire 3 can be increased. Among the elements other than aluminum, although the kind of the element depends on the kind of the steel wire 2, silicon is preferred from the viewpoint of suppression of generation of a brittle iron-aluminum alloy layer between iron contained in the steel wire 2 and aluminum contained in the plating film, increase in mechanical strength of the plating film and lowering in melting point of the molten aluminum 1, thereby increase in efficiency of plating of the steel wire 2.

[0027] The lower limit of the content of the above-mentioned element other than aluminum in the plating film is 0% by mass. From the viewpoint of sufficient exhibition of properties based on the element other than aluminum, the lower limit thereof is preferably 0.3% by mass or more, more preferably 0.5% by mass or more, and furthermore preferably 1% by mass or more. From the viewpoint of suppression of galvanic corrosion caused by contacting with an aluminum wire, the upper limit thereof is preferably 50% by mass or less, more preferably 20% by mass or less, and furthermore preferably 15% by mass or less.

[0028] Incidentally, an element such as nickel, chrome, zinc, copper or iron is possibly inevitably incorporated in the molten aluminum 1.

[0029] According to the present invention, the steel wire 2 is passed through the steel wire-introducing device 7 which is provided at a dipping area 6 for dipping the steel wire 2 in the molten aluminum 1, and then dipped in the molten aluminum 1. Since the present invention employs the process which includes passing the steel wire 2 through the steel wire-introducing device 7 which is provided at a dipping area 6 for dipping the steel wire 2 in the molten aluminum 1, and then dipping the steel wire 2 in the molten aluminum 1, a hot-dip aluminum-coated steel wire 3 having a plating film over the whole surface can be efficiently produced.

[0030] The steel wire-introducing device 7 according to the present invention will be described hereinafter with reference to Fig. 2. Fig. 2 is a schematic cross-sectional view showing one embodiment of the steel wire-introducing device 7 for hot-dip aluminum plating according to the present invention shown in Fig. 1 and Fig. 3.

[0031] As described above, the steel wire-introducing device 7 illustrated in Fig. 2 is used in the dipping area 6 for dipping the steel wire 2 in the molten aluminum 1 when the steel wire 2 is dipped in the molten aluminum 1, and continuously drawing up the steel wire 2 from the molten aluminum 1, to produce a hot-dip aluminum-coated steel wire 3.

[0032] As shown in Fig. 2, the steel wire-introducing device 7 has a through hole 8 for passing the steel wire 2 through the steel wire-introducing device 7 in the direction of arrow B, and a tubular body 9 having a total length L of 10 mm to 1000 mm. The total length L of the steel wire-introducing device 7 is 10 mm or more, preferably 30 mm or more, more preferably 40 mm or more, and furthermore preferably 50 mm or more, from the viewpoint of prevention of intrusion of the plating liquid of the molten aluminum 1 into an introducing port 9b for introducing the steel wire 2 when the dipping region 9a for dipping the steel wire 2 in the molten aluminum 1 is dipped in the molten aluminum 1, or prevention of intrusion of an oxide film which is generated on the surface of the molten aluminum 1 into the through hole 8 of the tubular body 9. The total length L of the steel wire-introducing device 7 is 1000 mm or less, preferably 800 mm or less, more preferably 500 mm or less, furthermore preferably 300 mm or less, and still furthermore preferably 100 mm or less, from the viewpoint of miniaturization of the tubular body 9, improvement in workability and efficient production of the hot-dip aluminum-coated steel wire 3 having a plating film over the whole surface.

[0033] The steel wire-introducing device 7 has the tubular body 9. The tubular body 9 has a dipping region 9a for dipping the tubular body 9 in the molten aluminum 1 from one end part of the tubular body 9, which is dipped in the molten aluminum 1 up to a virtual line P as shown in Fig. 2 within a length of 2 mm to 400 mm in a longitudinal direction of the tubular body 9. The length of the dipping region 9a is 2 mm or more, preferably 5 mm or more, and more preferably 10 mm or more, from the viewpoint of avoidance of affection of swaying of the surface of the molten aluminum 1, and efficient production of the hot-dip aluminum-coated steel wire 3 having a plating film over the whole surface. The length of the dipping region 9a is 400 mm or less, preferably 100 mm or less, more preferably 50 mm or less, and furthermore preferably 30 mm or less, from the viewpoint of improvement in workability and efficient production of the hot-dip aluminum-coated steel wire 3 having a plating film over the whole surface.

[0034] The length of the tubular body 9 in the longitudinal direction of the tubular body 9 where the tubular body 9 is not dipped in the molten aluminum 1 is preferably 5 mm or more, and more preferably 10 mm or more, from the viewpoint of prevention of intrusion of the plating liquid of the molten aluminum 1 into the introducing port 9b of the tubular body 9, or prevention of intrusion of an oxide film which is generated on the surface of the molten aluminum 1 into the through hole 8 of the tubular body 9.

[0035] A value of a ratio of an area of the opening part of the through hole 8 of the tubular body 9 to an area of the cross section of the steel wire 2 used in hot-dip aluminum plating, which is a so-called cross-section of the steel wire 2 [area of the opening part of the through hole 8 of the tubular body 9/area of the cross section of the steel wire 2] is 3 or more from the viewpoint of smooth introduction of the steel wire 2 into the through hole 8 of the tubular body 9 and efficient production of the hot-dip aluminum-coated steel wire 3 having a plating film over the whole surface. The above value of the ratio is 4000 or less, preferably 3000 or less, more preferably 2000 or less, and furthermore preferably 1000 or less, from the viewpoint of efficient production of the hot-dip aluminum-coated steel wire 3 having a plating film over the whole surface.

[0036] The shape of the opening part of the through hole 8 of the tubular body 9 can be circular, oval, or polygon such as square or rectangle, and the present invention is not limited by the shape thereof. The gap (clearance) between the opening part of the through-hole 8 of the tubular body 9 and the steel wire 2 is preferably 10 μ m or more, more preferably 20 μ m or more, furthermore preferably 50 μ m or more, and still more preferably 100 μ m or more, from the viewpoint of avoidance of sliding of an inner wall of the through-hole 8 of the tubular body 9 and the steel wire 2.

[0037] Incidentally, the opening parts of the through hole 8 provided in the tubular body 9 are an opening part 9c provided at the introducing port 9b for introducing the steel wire 2 from one end of the tubular body 9, and an opening part 9e provided at a discharge port 9d for discharging the steel wire 2 from another end of the tubular body 9 as shown in Fig. 2. The area and shape of the opening part 9c can be the same as those of the opening part 9e. Alternatively, the area and shape of the opening part 9c can be different from those of the opening part 9e. However, it is preferred that the area and shape of the opening part 9c are the same as those of the opening part 9e, respectively, as shown in Fig. 2 from the viewpoint that the steel wire 2 is smoothly passed through the through hole 8 of the tubular body 9, that sliding of the inner wall of the through hole 8 of the tubular body 9 and the steel wire 2 is avoided, and that the hot-dip aluminum-coated steel wire 3 having a plating film over the whole surface is efficiently produced.

[0038] It is preferred that the steel wire 2 is preheated from the viewpoint of efficient production of the hot-dip aluminum-coated steel wire 3 having a plating film over the whole surface. As a method for preheating the steel wire 2, there can be cited, for example, a method which includes passing the steel wire 2 through a heating device 17 before the steel wire 2 is passed through the steel wire-introducing device 7 as shown in Fig. 3, and the like, and the present invention is not limited only to the exemplified one. Incidentally, Fig. 3 is a schematic explanatory view showing another embodiment of the method for producing hot-dip aluminum-coated steel wire 3 according to the present invention. The heating device 17 includes, for example, a heating device as described in the following working examples.

[0039] A heating gas which is introduced into the heating device 17 includes, for example, air, inert gases such as nitrogen gas, argon gas and helium gas, and the like, and the present invention is not limited only to those exemplified ones. Among them, the inert gases are preferred from the viewpoint of prevention of oxidation of the molten aluminum 1 existing in the steel wire-introducing device 7 by ventilating a heating gas exhausted from the lower end of the heating device 17 to an introducing port equipped at the upper end of the steel wire-introducing device 7 which is provided below the heating device 17, to make the inside of the steel wire-introducing device 7 an inert gas atmosphere. The temperature of the heating gas cannot be absolutely determined because the temperature of the heating gas differs depending on the kind and diameter steel wire 2 being used, conditions such as a line speed of the steel wire 2 and a flow rate of the heating gas, and the like. Accordingly, it is preferred that the temperature of the heating gas is controlled so that the steel wire 2 is appropriately heated under the above conditions.

[0040] The preheating temperature of the steel wire 2 cannot be absolutely determined because the preheating temperature differs depending on the kind of the steel wire 2 and the like. The preheating temperature is preferably 50°C or higher, more preferably 60°C or higher, and furthermore preferably 70°C or higher, from the viewpoint of efficient production of the hot-dip aluminum-coated steel wire 3 having a plating film over the whole surface. The upper limit of the preheating temperature cannot be absolutely determined because the upper limit of the preheating temperature differs depending on the kind of the steel wire 2 and the like. It is preferred that the upper limit of the preheating temperature is usually 800°C or lower in consideration of energy efficiency. Incidentally, the above-mentioned preheating temperature is a temperature determined in accordance with a method as described in the following working examples.

[0041] Next, as shown in Fig. 1 and Fig. 3, the steel wire 2 dipped in the molten aluminum 1 is drawn up upward from the surface 10 of the molten aluminum 1, to form a plating film made of the molten aluminum 1 on the surface of the steel wire 2, and thereby the hot-dip aluminum-coated steel wire 3 is obtained.

[0042] When the steel wire 2 is drawn up from the molten aluminum 1 in the direction of arrow C (upward) as illustrated in Fig. 4, it is preferred that a stabilization member 11 is contacted with the steel wire 2 at a boundary between the steel wire 2 and the surface 10 of the molten aluminum 1.

[0043] Incidentally, Fig. 4 is a schematic explanatory view showing a boundary portion between the steel wire 2 and the surface 10 of the molten aluminum 1 when the steel wire 2 is drawn up from the molten aluminum 1 in the method for producing a hot-dip aluminum-coated steel wire according to the present invention.

[0044] The stabilization member 11 includes, for example, a square rod made of stainless steel, in which a heat-resistant cloth 11a is wound around the surface of the square rod, and the like. The heat-resistant cloth 11a wound around the surface of the square rod includes, for example, woven fabric and non-woven fabric, containing a heat-resistant fiber such as a ceramic fiber, a carbon fiber, an aramid fiber or an imide fiber, and the present invention is not limited only to those exemplified ones. It is preferred that a virgin surface (new surface) of the heat-resistant cloth 11a of the stabilization member 11 is contacted with the steel wire 2 from the viewpoint of suppression of deposition of an aluminum lump on the surface of the hot-dip aluminum-coated steel wire 3.

[0045] It is preferred that the stabilization member 11 is contacted with both of the surface 10 of the molten aluminum 1 and the steel wire 2 at the same time. When the stabilization member 11 is contacted with both of the surface 10 of the molten aluminum 1 and the steel wire 2 at the same time as mentioned above, pulsation of the surface 10 of the molten aluminum 1 can be suppressed, and minute vibration of the steel wire 2 can be suppressed by the stabilization member 11 during drawing up the steel wire 2 in contact of the steel wire 2 with the stabilization member 11. Thereby a plating film 18 of the molten aluminum 1 can be uniformly formed on the surface of the steel wire 2. Incidentally, when the stabilization member 11 is contacted with the steel wire 2, it is preferred that the stabilization member 11 is slightly pressed toward the steel wire 2 in order to apply tension to the steel wire 2 as occasion demands from the viewpoint of

suppression of minute vibration of the steel wire 2.

[0046] In the embodiments illustrated in Fig. 1 and Fig. 3, a nozzle 12 for blowing an inert gas to the boundary between the steel wire 2 and the surface 10 of the molten aluminum 1 is provided. In the embodiment illustrated in Fig. 4, a tip end 12a of a nozzle 12 is provided so that an inert gas is blown from the tip end 12a to the boundary between the steel

wire 2 and the surface 10 of the molten aluminum 1.

[0047] According to the present invention, the hot-dip aluminum-coated steel wire 3 having a uniform outer diameter and little aluminum lump on its surface can be efficiently produced by appropriately controlling the distance (the shortest distance) from the steel wire 2 to a tip end 12a of the nozzle 12, the temperature of the inert gas discharged from the tip end 12a of the nozzle 12, an inner diameter of the tip end 12a of the nozzle 12, and a volume flow rate of the inert gas discharged from the nozzle 12.

[0048] The distance (the shortest distance) from the steel wire 2 to the tip end 12a of the nozzle 12 is preferably 1 mm or more from the viewpoint of avoidance of a contact of the tip end 12a with the steel wire 2, and efficient production of the hot-dip aluminum-coated steel wire 3. The distance (the shortest distance) from the steel wire 2 to the tip end 12a of the nozzle 12 is preferably 50 mm or less, more preferably 40 mm or less, furthermore preferably 30 mm or less, and still further preferably 10 mm or less, from the viewpoint of production of a hot-dip aluminum-coated steel wire 3 having a uniform outer diameter and little aluminum lump on its surface.

[0049] The inner diameter of the tip end 12a of the nozzle 12 is preferably 1 mm or more, and more preferably 2 mm or more, from the viewpoint of efficient production of a hot-dip aluminum-coated steel wire 3 by accurately blowing an inert gas from the tip end 12a of the nozzle 12 to the boundary between the steel wire 2 and the surface 10 of the molten aluminum 1. The inner diameter of the tip end 12a of the nozzle 12 is preferably 15 mm or less, more preferably 10 mm or less, and furthermore preferably 5 mm or less, from the viewpoint of production of a hot-dip aluminum-coated steel wire 3 having a uniform outer diameter and little aluminum lump on its surface.

[0050] The inert gas can be provided, for example, from an inert gas providing apparatus 13 through a pipe 14 to the nozzle 12 as shown in Fig. 1 and Fig. 3. Incidentally, a flow controller such as a valve (not shown in the figure) can be provided in the inert gas providing apparatus 13 or the pipe 14 in order to control the flow rate of the inert gas.

[0051] The inert gas means a gas which is inert to molten aluminum. Examples of the inert gas include, for example, nitrogen gas, argon gas, helium gas and the like, and the present invention is not limited only to those exemplified ones. Among the inert gases, nitrogen gas is preferable. The inert gas may contain, for example, oxygen gas, carbon dioxide gas and the like within a scope which would not hinder an object of the present invention.

[0052] In Fig. 4, the volume flow rate of the inert gas discharged from the tip end 12a of the nozzle 12 is preferably 2 L (liter)/min or more, more preferably 5 L/min or more, and furthermore preferably 10 L/min or more, from the viewpoint of production of a hot-dip aluminum-coated steel wire 3 having a uniform outer diameter and little aluminum lump on its surface. The volume flow rate of the inert gas thereof is preferably 200 L/min or less, more preferably 150 L/min or less, and furthermore preferably 100 L/min or less, from the viewpoint of suppression of deposition of an aluminum lump on the surface of the hot-dip aluminum-coated steel wire 3 due to scattering of the molten aluminum 1.

[0053] The temperature of the inert gas discharged from the tip end 12a of the nozzle 12 is preferably 200°C or higher, more preferably 300°C or higher, and furthermore preferably 400°C or higher, from the viewpoint of production of a hot-dip aluminum-coated steel wire 3 having a uniform outer diameter and little aluminum lump on its surface. The temperature of the inert gas thereof is preferably 800°C or lower, more preferably 780°C or lower, and furthermore preferably 750°C or lower, from the viewpoint of increase in thermal efficiency. Incidentally, the temperature of the inert gas discharged from the tip end 12a of the nozzle 12 is a temperature as determined by inserting a thermocouple for measuring a temperature, such as a sheath thermocouple having a diameter of 1.6 mm into the inert gas apart from the tip end 12a of the nozzle 12 in a distance of 2 mm.

[0054] The speed for drawing up the hot-dip aluminum-coated steel wire 3 from the surface 10 of the molten aluminum 1 is not particularly limited. It is preferred that the speed is appropriately controlled in accordance with the average thickness of a plating film formed on the surface of the hot-dip aluminum-coated steel wire 3. The average thickness of the plating film formed on the surface of the hot-dip aluminum-coated steel wire 3 can be appropriately controlled by adjusting the speed for drawing up the hot-dip aluminum-coated steel wire 3.

[0055] In the present invention, even when the speed for drawing up the hot-dip aluminum-coated steel wire 3 is controlled to a high speed such as 200 m/min or more, the hot-dip aluminum-coated steel wire 3 having a uniform outer diameter and a plating film 18 formed over the whole surface can be produced. Accordingly, the method for producing a hot-dip aluminum-coated steel wire 3 according to the present invention is excellent in industrial productivity of the hot-dip aluminum-coated steel wire 3, because the hot-dip aluminum-coated steel wire 3 having a plating film 18 formed over the whole surface can be efficiently produced. Incidentally, the speed for drawing up the hot-dip aluminum-coated steel wire 3 is not particularly limited. The speed for drawing up the hot-dip aluminum-coated steel wire 3 is preferably 200 m/min or less, more preferably 100 m/min or more, and furthermore preferably 50 m/min or less, from the viewpoint of efficient production of the hot-dip aluminum-coated steel wire 3 having a plating film over the whole surface.

[0056] Incidentally, a cooling device 15 can be provided above the nozzle 12 as occasion demands as illustrated in

Fig. 1 and Fig. 3 in order to cool the hot-dip aluminum-coated steel wire 3 in the course of drawing up of the hot-dip aluminum-coated steel wire 3, and efficiently solidify the plating film 18 formed on the surface of the hot-dip aluminum-coated steel wire 3. The hot-dip aluminum-coated steel wire 3 can be cooled by blowing, for example, gas, liquid mist or the like to the hot-dip aluminum-coated steel wire 3 in the cooling device 15.

[0057] The hot-dip aluminum-coated steel wire 3 produced in the above can be collected by means of, for example, a winding device 16 or the like.

[0058] The average thickness of the plating film formed on the surface of the hot-dip aluminum-coated steel wire 3 is preferably 2 μm to 20 μm or so, more preferably 4 μm to 15 μm or so, from the viewpoint of suppression of exposure of the steel wire 2 included in the hot-dip aluminum-coated steel wire 3 to the air in carrying out a process such as a wire stranding process or a crimping process, and increase in mechanical strength per unit outer diameter of the hot-dip aluminum-coated steel wire 3.

[0059] The hot-dip aluminum-coated steel wire 3 obtained in the above can be subjected to a drawing process using dies and the like as occasion demands so that the hot-dip aluminum-coated steel wire 3 has an appropriate diameter.

[0060] The hot-dip aluminum-coated steel wire 3 obtained by the method for producing a hot-dip aluminum-coated steel wire according to the present invention can be suitably used, for example, in a wire harness of an automobile, and the like.

EXAMPLES

[0061] Next, the present invention will be more specifically described based on working examples. However, the present invention is not limited only to those working examples.

Examples 1 to 39 and Comparative Examples 1 to 3

[0062] A hot-dip aluminum-coated steel wire was produced based on the embodiment as illustrated in Fig. 1.

[0063] As a steel wire, a steel wire having a diameter shown in Tables 1 to 3 and made of steel shown in Tables 1 to 3 was used. The term "37A" listed in the column of "kind" of "steel wire" in Table 3 means a steel wire made of high carbon steel containing 0.37% by mass of carbon.

[0064] Incidentally, the steel wire was subjected to degreasing by dipping the steel wire in a degreasing liquid containing sodium orthosilicate and a surfactant, before the steel wire was dipped in the hot-dip aluminum.

[0065] In addition, as a device for introducing a steel wire, a device 7 for introducing a steel wire shown in Fig. 2, which was produced by assembling blocks or square bars made of stainless steel, was used. The device 7 for introducing a steel wire had a total length L of 300 mm, and the shape, size and area of the opening part 9c of the introducing port 9b of the through hole 8 were the same as those of the opening part 9e of the discharge port 9d of the through hole 8. The shape, size and area of the opening part of the through hole 8 of the device 7 for introducing a steel wire, and the ratio of the area of the opening part to the area of the cross-section of the steel wire (hereinafter, referred to as "value of area ratio") are shown in Tables 1 to 3. The dipping region 9a of 30 mm from the lower end of the steel wire-introducing device 7 was dipped in the molten aluminum, and the steel wire being introduced into the steel wire-introducing device 7 was dipped in the molten aluminum as it was.

[0066] As the molten aluminum, molten aluminum having an aluminum purity of 99.7% or more (referred to as "Al" in the column "kind" of "hot-dip Al" in Tables 1 to 3), molten aluminum containing 4% by mass of silicon (referred to as "4%Si" in the column "kind" of "hot-dip Al" in Tables 1 to 3), molten aluminum containing 8% by mass of silicon (referred to as "8%Si" in the column "kind" of "hot-dip Al" in Tables 1 to 3), molten aluminum containing 11% by mass of silicon (referred to as "11%Si" in the column "kind" of "hot-dip Al" in Tables 1 to 3) or molten aluminum containing 13 % by mass of silicon (referred to as "13%Si" in the column "kind" of "hot-dip Al" in Tables 1 to 3) was used. The steel wire was dipped in the molten aluminum at a temperature of the molten aluminum shown in Tables 1 to 3 at a line speed (speed of drawing up of the steel wire) shown in Tables 1 to 3, and then the steel wire was drawn up from the molten aluminum.

[0067] A nozzle having an inner diameter of 3 mm at its tip was provided so that the tip of the nozzle was positioned at a place apart from the steel wire in a distance of 2 mm. An inert gas (nitrogen gas) of which temperature was controlled to 600 °C was discharged from the tip of the nozzle at a volume flow rate of 10 L/min, and was blown to the boundary between the steel wire and the surface of the molten aluminum.

[0068] The above operations were carried out, to obtain a hot-dip aluminum-coated steel wire having a plating film of an average thickness shown in Tables 1 to 3. Incidentally, a method for determining the average thickness of the plating film is as follows:

[Method for determining average thickness of plating film]

[0069] The average thickness of a plating film of a hot-dip aluminum-coated steel wire obtained in each of working examples and comparative examples was determined on the basis of an embodiment shown in Fig. 5. Fig. 5 is a schematic explanatory view showing one embodiment of a method for determining an average thickness of a plating film of a hot-dip aluminum-coated steel wire obtained in each of working examples and comparative examples.

[0070] As a device 19 for measuring a diameter of a steel wire by passing through the steel wire, a device for measuring a diameter having two optical micrometers each of which was commercially available from KEYENCE CORPORATION under the product number of LS-7000 was used as shown in Fig. 5. The device 19 for measuring a diameter had a pair of a pulley 19c and a pulley 19d which were positioned in a vertical direction against the steel wire, and a pair of a light emitting unit 19a and a light receiving unit 19b which were arranged in a horizontal direction at a central position between the pulley 19c and the pulley 19d. The light emitting unit 19a and the light receiving unit 19b were arranged so that the light emitting unit 19a and the light receiving unit 19b were opposed to each other. The light emitting unit 19a and the light receiving unit 19b adjacent each other were arranged so that an angle between the light emitting unit 19a and the light receiving unit 19b was 90° as shown in Fig. 5.

[0071] While the hot-dip aluminum-coated steel wire 3 having a length of 100 m obtained in each working example or each comparative example was being run at a line speed of 100 m/min in a direction of arrow D between the pulley 19c and the pulley 19d, the outer diameter of the hot-dip aluminum-coated steel wire 3 was measured at an interval of a length of about 1.4 mm in the longitudinal direction of the aluminum-plated steel wire 3 by means of the device 19 for measuring a diameter. The number of measurement points of the outer diameter was adjusted to about 71000 points.

[0072] Next, an average value of the outer diameters of the hot-dip aluminum-coated steel wire as measured in the above was calculated. The value of the diameter of the steel wire before forming a plating film (diameter of steel wire shown in the following Tables 1 to 3) was subtracted from the average value, and an obtained value was divided by 2, to give an average thickness of a plating film. The results are shown in Tables 1 to 3.

[Stability of plating film]

[0073] As a property of the hot-dip aluminum-coated steel wire obtained in each working example or each comparative example, stability of a plating film was examined in accordance with the following method. The results are shown in Tables 1 to 3.

[0074] The surface of the hot-dip aluminum-coated steel wire having a length of 100 m, obtained in each working example or each comparative example was observed over the entire length with a naked eye by using a microscope. When a portion where a plating film was not formed on the surface of the steel wire was observed, the length of the portion where a plating film was not formed was measured by pulling out the steel wire within a range from 250 mm before the portion where a plating film was not formed to 250 mm after the portion where a plating film was not formed [hereinafter referred to as observed length (500mm)]. The length of the portion where a plating film was not formed in the longitudinal direction (hereinafter referred to as non-plated length) was measured, and non-plated rate was determined in accordance with the following equation:

$$\begin{aligned} & \text{[Non-plated rate]} \\ & = \{[\text{Non-plated length (mm)}] / [\text{Observed length (mm)}]\} \times 100. \end{aligned}$$

The stability of the plating film was evaluated in accordance with the following evaluation criteria.

(Evaluation criteria of stability of plating film)

[0075]

- 5: Non-plated rate is less than 1% (pass).
- 4: Non-plated rate is 1% or more and less than 5% (pass).
- 3: Non-plating rate is 5% or more and less than 30% (pass).
- 2: Non-plated rate is 30% or more and less than 60% (failure).
- 1: Non-plated rate is 60% or more (failure).

[Table 1]

Ex. No.	Steel wire		Hot-dip Al		Line speed (m/min)	Opening part of through hole of device for introducing a steel wire			Value of area ratio	Average thickness of plating film (μm)	Stability of plating film
	Diameter (mm)	Kind	Kind	Temp. ($^{\circ}\text{C}$)		Shape	Size (mm)	Area (mm^2)			
Ex. 1	0.20	SUS304	8%Si	700	25	Rectangle	0.25×3.0	0.75	24	4.0	5
Ex. 2	0.20	SUS304	8% Si	700	50	Rectangle	0.25×3.0	0.75	24	4.6	5
Ex. 3	0.20	SUS304	8%Si	700	100	Rectangle	0.25×3.0	0.75	24	4.8	4
Ex. 4	0.20	SUS304	8%Si	700	25	Rectangle	5.0×5.0	25	800	4.0	5
Ex. 5	0.20	SUS304	8%Si	700	50	Rectangle	5.0×5.0	25	800	4.6	5
Ex. 6	0.20	SUS304	8%Si	700	100	Rectangle	5.0×5.0	25	800	4.7	4
Ex. 7	0.20	SUS304	8%Si	700	25	Rectangle	7.0×7.0	49	1560	3.9	3
Ex. 8	0.20	SUS304	8%Si	700	50	Rectangle	7.0×7.0	49	1560	4.5	3
Ex. 9	0.20	SUS304	8%Si	700	100	Rectangle	7.0×7.0	49	1560	4.7	3
Ex. 10	0.20	SUS304	8%Si	700	25	Rectangle	10×10	100	3180	3.9	3
Ex. 11	0.20	SUS304	8%Si	700	50	Rectangle	10×10	100	3180	4.2	3
Ex. 12	0.20	SUS304	8%Si	700	100	Rectangle	10×10	100	3180	4.6	3
Ex. 13	0.20	SUS304	8%Si	700	50	Rectangle	0.31×0.31	0.096	3.1	4.5	5

(continued)

Ex. No.	Steel wire		Hot-dip Al		Line speed (m/min)	Opening part of through hole of device for introducing a steel wire			Value of area ratio	Average thickness of plating film (μm)	Stability of plating film
	Diameter (mm)	Kind	Kind	Temp. ($^{\circ}\text{C}$)		Shape	Size (mm)	Area (mm^2)			
Ex. 14	0.20	SUS304	8%Si	700	50	Round	$\phi 0.35$	0.096	3.1	4.4	5
Ex. 15	0.20	SUS304	8%Si	700	50	Round	$\phi 2.0$	3.14	100	4.6	5
Ex. 16	0.20	SUS304	8%Si	700	50	Round	$\phi 5.0$	20	640	4.4	5
Ex. 17	0.20	SUS304	8%Si	700	50	Round	$\phi 8.0$	50	1600	4.3	3
Ex. 18	0.20	SUS304	8%Si	700	50	Round	$\phi 12.0$	113	3600	4.7	3
(Note)											
"Value of area ratio" means a value of area ratio [area of opening part of through hole / area of cross section of steel wire].											

[Table 2]

Ex. No.	Steel wire		Hot-dip Al		Line, speed (m/min)	Opening part of through hole of device for introducing a steel wire			Value of area ratio	Average thickness of plating film (μm)	Stability of plating film
	Diameter (mm)	Kind	Kind	Temp. (°C)		Shape	Size (mm)	Area (mm^2)			
Ex. 19	0.20	SUS304	8%Si	685	50	Rectangle	1.0×2.0	2.0	64	4.2	5
Ex. 20	0.20	SUS304	8%Si	720	50	Rectangle	1.0×2.0	2.0	64	4.5	5
Ex. 21	0.20	SUS304	4%Si	685	50	Rectangle	1.0×2.0	2.0	64	4.6	5
Ex. 22	0.20	SUS304	11%Si	685	50	Rectangle	1.0×2.0	2.0	64	4.3	5
Ex. 23	0.07	SUS304	8%Si	700	50	Rectangle	1.0×2.0	2.0	520	4.0	5
Ex. 24	0.10	SUS304	8%Si	700	50	Rectangle	1.0×2.0	2.0	255	4.5	5
Ex. 25	0.15	SUS304	8%Si	700	50	Rectangle	1.0×2.0	2.0	113	4.6	5
Ex. 26	0.30	SUS304	8%Si	700	50	Rectangle	2.0×3.0	6.0	85	4.5	5
Ex. 27	0.60	SUS304	8%Si	700	50	Rectangle	2.0×3.0	6.0	21	4.4	5
Ex. 28	1.00	SUS304	8%Si	700	50	Rectangle	2.0×3.0	6.0	8	4.6	5
Ex. 29	0.20	SUS430	8%Si	700	25	Rectangle	0.8×3.0	2.4	76	3.8	5
Ex. 30	0.20	SUS430	8%Si	700	50	Rectangle	0.8×3.0	2.4	76	4.3	5
Ex. 31	0.20	SUS430	8%Si	700	100	Rectangle	0.8×3.0	2.4	76	4.4	4
Ex. 32	0.20	SUS304	13%Si	685	50	Rectangle	1.0×2.0	2.0	64	4.6	5
Ex. 33	0.20	SUS304	Al	700	50	Rectangle	1.0×2.0	2.0	64	4.2	5
Comp. Ex. 1	0.20	SUS304	8%Si	700	25	No	installation		-	3.4	2
Comp. Ex. 2	0.20	SUS304	8%Si	700	50	No	installation		-	3.6	1
Comp. Ex. 3	0.20	SUS304	8%Si	700	100	No	installation		-	3.7	1

(Note)

"Value of area ratio" means a value of area ratio [area of opening part of through hole / area of cross section of steel wire].

[Table 3]

Ex. No.	Steel wire		Hot-dip Al		Line speed (m/min)	Opening part of through hole of device for introducing a steel wire			Value of area ratio	Average thickness of plating film (μm)	Stability of plating film
	Diameter (mm)	Kind	Kind	Temp. ($^{\circ}\text{C}$)		Shape	Size (mm)	Area (mm^2)			
Ex. 34	0.20	37A	8%Si	700	50	Rectangle	0.25×3.0	0.75	24	4.3	5
Ex. 35	0.20	37A	8%Si	700	50	Rectangle	1.0×2.0	2.0	64	4.4	5
Ex. 36	0.20	37A	8%Si	700	50	Rectangle	5.0×5.0	25	800	4.4	5
Ex. 37	0.20	37A	8%Si	700	50	Rectangle	7.0×7.0	49	1560	4.5	3
Ex. 38	0.20	37A	8%Si	700	50	Rectangle	10×10	100	3180	4.2	3
Ex. 39	0.20	37A	8%Si	700	50	Round	$\phi 2.0$	3.14	100	4.2	5
(Note) "Value of area ratio" means a value of area ratio [area of opening part of through hole / area of cross section of steel wire].											

Examples 40 to 67 and Comparative Example 4

[0076] A hot-dip aluminum-coated steel wire was produced based on the embodiment as illustrated in Fig. 3. As a steel wire, a steel wire having a diameter shown in Tables 4 and 5, and made of steel shown in Tables 4 and 5 was used. The term "37A" listed in Table 5 means a steel wire made of high carbon steel containing 0.37% by mass of carbon.

[0077] Incidentally, the steel wire was subjected to degreasing by dipping the steel wire in a degreasing liquid containing sodium orthosilicate and a surfactant, before the steel wire was dipped in the hot-dip aluminum.

[0078] In addition, the steel wire was preheated at a preheating temperature shown in Tables 4 and 5 by introducing the steel wire into a heating device, before the steel wire was introduced into a steel wire-introducing device. As the heating device, a tubular heater (not shown in the figure) was provided just before the steel wire-introducing device. A Kanthal® wire wound in a coil shape was built in the heater. The heater was connected with a gas-introducing system for providing nitrogen gas (not shown in the figure), and heated nitrogen gas was introduced into the heating device, to preheat the steel wire in nitrogen gas atmosphere. Incidentally, a steel wire connected with a thermocouple was prepared, and the thermocouple was passed through the heating device together with the steel wire, to determine the preheating temperature.

[0079] As a device for introducing a steel wire, a device 7 for introducing a steel wire shown in Fig. 2, which was produced by assembling blocks or square bars made of stainless steel, was used. The device 7 for introducing a steel wire had a total length L of 100 mm, and the shape, size and area of the opening part 9c of the introducing port 9b of the through hole 8 were the same as those of the opening part 9e of the discharge port 9d of the through hole 8. The shape, size and area of the opening part of the through hole 8 of the device 7 for introducing a steel wire, and the value of area ratio are shown in Tables 4 and 5. The dipping region 9a of 10 mm from the lower end of the steel wire-introducing device 7 was dipped in the molten aluminum, and the steel wire being introduced into the steel wire-introducing device 7 was dipped in the molten aluminum as it was.

[0080] As the molten aluminum, molten aluminum containing 8% by mass of silicon (referred to as "8%Si" in the column "kind" of "hot-dip Al" in Tables 4 and 5) was used. The steel wire was dipped in the molten aluminum at a temperature of the molten aluminum shown in Tables 4 and 5 at a line speed (speed of drawing up of steel wire) shown in Tables 4 and 5, and then the steel wire was drawn up from the molten aluminum.

[0081] In addition, a nozzle having an inner diameter of 3 mm at its tip was provided so that the tip of the nozzle was positioned at a place apart from the steel wire in a distance of 2 mm. An inert gas (nitrogen gas) of which temperature was controlled to 600°C was discharged from the tip of the nozzle at a volume flow rate of 10 L/min, and was blown to the boundary between the steel wire and the surface of the molten aluminum.

[0082] The above operations were carried out, to obtain a hot-dip aluminum-coated steel wire having a plating film of an average thickness shown in Tables 4 and 5.

[0083] Next, the average thickness of a plating film and stability of a plating film of the hot-dip aluminum-coated steel wire obtained in the above were examined in the same manner as mentioned above. Its results are shown in Table 4 and 5.

[Table 4]

Ex. No.	Steel wire		Hot-dip Al		Line speed (m/min)	Heating device		Opening part of through hole of device for introducing a steel wire			Value of area ratio	Average thickness of plating film (μm)	Stability of plating film
	Diameter (mm)	Kind	Kind	Temp. ($^{\circ}\text{C}$)		Preheating temp. ($^{\circ}\text{C}$)	Introduced gas	Shape	Size (mm)	Area (mm^2)			
Ex. 40	0.20	SUS304	8%Si	700	300	82	Nitrogen	Rectangle	0.25×30	0.75	24	5.9	3
Ex. 41	0.20	SUS304	8%Si	700	300	168	Nitrogen	Rectangle	0.25×3.0	0.75	24	6.0	4
Ex. 42	0.20	SUS304	8%Si	700	300	250	Nitrogen	Rectangle	0.25×3.0	0.75	24	5.8	4
Ex. 43	0.20	SUS304	8%Si	700	300	390	Nitrogen	Rectangle	0.25×3.0	0.75	24	5.7	5
Ex. 44	0.20	SUS304	8%Si	700	300	582	Nitrogen	Rectangle	0.25×3.0	0.75	24	6.1	5
Ex. 45	0.20	SUS304	8%Si	700	300	710	Nitrogen	Rectangle	0.25×3.0	0.75	24	5.8	5
Ex. 46	0.20	SUS304	8%Si	700	300	330	Nitrogen	Rectangle	0.25×3.0	0.75	24	6.4	5
Ex. 47	0.20	SUS304	8%Si	700	300	330	Nitrogen	Round	$\phi 2.0$	3.14	100	5.9	5
Ex. 48	0.20	SUS304	8%Si	685	300	390	Nitrogen	Rectangle	0.8×3.0	2.4	76	6.2	5
Ex. 49	0.20	SUS304	8%Si	720	300	390	Nitrogen	Rectangle	0.8×3.0	2.4	76	5.6	5
Ex. 50	0.20	SUS304	8%Si	685	300	390	Nitrogen	Rectangle	0.8×3.0	2.4	76	5.5	5
Ex. 51	0.20	SUS304	8%Si	700	300	390	Nitrogen	Rectangle	0.31×0.31	0.096	3.1	4.4	5
Ex. 52	0.20	SUS304	8%Si	700	300	390	Nitrogen	Round	$\phi 0.35$	0.096	3.1	4.5	5

(continued)

Ex. No.	Steel wire		Hot-dip Al		Line speed (m/min)	Heating device		Opening part of through hole of device for introducing a steel wire			Value of area ratio	Average thickness of plating film (μm)	Stability of plating film
	Diameter (mm)	Kind	Kind	Temp. (°C)		Preheating temp. (°C)	Introduced gas	Shape	Size (mm)	Area (mm ²)			
Ex. 53	0.07	SUS304	8%Si	700	600	322	Nitrogen	Rectangle	1.0×2.0	2.0	520	4.8	5
Ex. 54	0.10	SUS304	8%Si	700	600	333	Nitrogen	Rectangle	1.0×2.0	2.0	255	5.2	5
(Note) "Value of area ratio" means a value of area ratio [area of opening part of through hole / area of cross section of steel wire].													

[Table 5]

Ex. No.	Steel wire		Hot-dip Al		Line speed (m/min)	Heating device		Opening part of through hole of device for introducing a steel wire			Value of area ratio	Average thickness of plating film (μm)	Stability of plating film
	Diameter (mm)	Kind	Kind	Preheating temp. ($^{\circ}\text{C}$)		Preheating temp. ($^{\circ}\text{C}$)	Introduced gas	Shape	Size (mm)	Area (mm^2)			
Ex. 55	0.15	SUS304	8%Si	700	200	315	Nitrogen	Rectangle	1.0×2.0	2.0	113	5.3	5
Ex. 56	0.30	SUS304	8%Si	700	300	302	Nitrogen	Rectangle	2.0×3.0	6.0	85	9.3	5
Ex. 57	0.60	SUS304	8%Si	700	300	282	Nitrogen	Rectangle	2.0×3.0	6.0	21	12.3	5
Ex. 58	1.00	SUS304	8%Si	700	300	240	Nitrogen	Rectangle	2.0×3.0	6.0	8	14.9	5
Ex. 59	0.20	SUS430	8%Si	700	300	82	Nitrogen	Rectangle	0.25×3.0	0.75	24	5.9	3
Ex. 60	0.20	SUS430	8%Si	700	300	168	Nitrogen	Rectangle	0.25×3.0	0.75	24	6.0	4
Ex. 61	0.20	SUS430	8%Si	700	300	390	Nitrogen	Rectangle	0.25×3.0	0.75	24	5.8	5
Ex. 62	0.20	37A	8%Si	700	300	82	Nitrogen	Rectangle	0.25×3.0	0.75	24	5.9	3
Ex. 63	0.20	37A	8%Si	700	300	168	Nitrogen	Rectangle	0.25×3.0	0.75	24	6.1	4
Ex. 64	0.20	37A	8%Si	700	300	390	Nitrogen	Rectangle	0.25×3.0	0.75	24	5.7	5
Ex. 65	0.20	37A	8%Si	700	300	710	Nitrogen	Rectangle	0.25×3.0	0.75	24	6.2	5
Ex. 66	0.20	37A	8%Si	700	400	330	Nitrogen	Rectangle	0.25×3.0	0.75	24	5.4	5
Ex. 67	0.20	37A	8%Si	700	300	390	Nitrogen	Round	ϕ 2.0	3.14	100	5.5	5
Comp. Ex. 4	0.20	SUS304	8%Si	700	300	260	Nitrogen	No installation			-	3.8	1

(Note)

"Value of area ratio" means a value of area ratio [area of opening part of through hole / area of cross section of steel wire].

Examples 68 to 83

[0084] A hot-dip aluminum-coated steel wire was produced based on the embodiment as illustrated in Fig. 1.

[0085] As a steel wire, a steel wire having a diameter shown in Table 6, and made of steel shown in Table 6 was used. The term "37A" listed in Table 6 means a steel wire made of high carbon steel containing 0.37% by mass of carbon.

[0086] Incidentally, the steel wire was subjected to degreasing by dipping the steel wire in a degreasing liquid containing sodium orthosilicate and a surfactant, before the steel wire was dipped in the hot-dip aluminum.

[0087] As a device for introducing a steel wire, a device 7 for introducing a steel wire shown in Fig. 2, which was produced by assembling blocks or square bars made of stainless steel, was used. The device 7 for introducing a steel wire had a total length L of 800 mm, and the shape, size and area of the opening part 9c of the introducing port 9b of the through hole 8 were the same as those of the opening part 9e of the discharge port 9d of the through hole 8. The shape, size and area of the opening part of the through hole 8 of the device 7 for introducing a steel wire, and the value of area ratio are shown in Table 6. The dipping region 9a of 100 mm from the lower end of the steel wire-introducing device 7 was dipped in the molten aluminum, and the steel wire being introduced into the steel wire-introducing device 7 was dipped in the molten aluminum as it was.

[0088] As the molten aluminum, molten aluminum containing 8 % by mass of silicon (referred to as "8%Si" in the column "kind" of "hot-dip Al" in Table 6), was used. The steel wire was dipped in the molten aluminum at a temperature of the molten aluminum shown in Table 6 at a line speed (speed of drawing up of steel wire) shown in Table 6, and then the steel wire was drawn up from the molten aluminum.

[0089] A nozzle having an inner diameter of 3 mm at its tip was provided so that the tip of the nozzle was positioned at a place apart from the steel wire in a distance of 2 mm. An inert gas (nitrogen gas) of which temperature was controlled to 600°C was discharged from the tip of the nozzle at a volume flow rate of 10 L/min, and blown to the boundary between the steel wire and the surface of the molten aluminum.

[0090] The above operations were carried out, to obtain a hot-dip aluminum-coated steel wire having a plating film of an average thickness shown in Table 6.

[0091] Next, the average thickness of a plating film and stability of a plating film of the hot-dip aluminum-coated steel wire obtained in the above were examined in the same manner as mentioned above. Its results are shown in Table 6.

[Table 6]

Ex. No.	Steel wire		Hot-dip Al		Line speed (m/min)	Opening part of through hole of device for introducing a steel wire			Value of area ratio	Average thickness of plating film (μm)	Stability of plating film
	Diameter (mm)	Kind	Kind	Preheating temp. (°C)		Shape	Size (mm)	Area (mm ²)			
Ex. 68	0.20	SUS304	8%Si	700	50	Rectangle	0.25×3.0	0.75	24	4.5	5
Ex. 69	0.20	SUS304	8%Si	700	50	Rectangle	5.0×3.0	15	480	4.4	5
Ex. 70	0.20	SUS304	8%Si	700	50	Rectangle	7.0×3.0	21	670	4.6	3
Ex. 71	0.20	SUS304	8%Si	700	50	Rectangle	10×10	100	3180	4.3	3
Ex. 72	0.20	SUS430	8%Si	700	50	Rectangle	0.31×0.31	0.096	3.1	4.3	5
Ex. 73	0.20	SUS430	8%Si	700	50	Round	φ0.35	0.096	3.1	4.8	5
Ex. 74	0.20	SUS430	8%Si	700	50	Round	φ2.0	3.14	100	4.6	5
Ex. 75	0.20	SUS430	8%Si	700	50	Round	φ5.0	19.63	625	4.7	5
Ex. 76	0.20	SUS430	8%Si	700	50	Round	φ8.0	50.24	1600	4.6	3
Ex. 77	0.20	SUS430	8%Si	700	50	Round	φ12.0	113	3600	4.9	3
Ex. 78	0.20	37A	8%Si	700	50	Rectangle	0.25×3.0	0.75	24	4.5	5
Ex. 79	0.20	37A	8%Si	700	50	Rectangle	1.0×2.0	2.0	64	4.6	5
Ex. 80	0.20	37A	8%Si	700	50	Rectangle	5.0×5.0	25	800	4.8	5

(continued)

Ex. No.	Steel wire		Hot-dip Al		Line speed (m/min)	Opening part of through hole of device for introducing a steel wire			Value of area ratio	Average thickness of plating film (μm)	Stability of plating film
	Diameter (mm)	Kind	Kind	Preheating temp. (°C)		Shape	Size (mm)	Area (mm ²)			
Ex. 81	0.20	37A	8%Si	700	50	Rectangle	7.0×7.0	49	1560	4.7	3
Ex. 82	0.20	37A	8%Si	700	50	Rectangle	10×10	100	3180	4.7	3
Ex. 83	0.20	37A	8%Si	700	50	Round	φ2.0	3.14	100	4.6	5
(Note) "Value of area ratio" means a value of area ratio [area of opening part of through hole / area of cross section of steel wire].											

[0092] From the results shown in Tables 1 to 6, according to the method for producing a hot-dip aluminum-coated steel wire of each of the working examples, it can be seen that excellent effects such that a hot-dip aluminum-coated steel wire having a plating film over the whole surface can be efficiently produced.

[0093] In contrast, in Comparative Examples 1 to 4, a steel wire-introducing device was not employed. Therefore, an oxide film floating on the surface of the molten aluminum was included in the molten aluminum when a steel wire was dipped in the molten aluminum. Accordingly, a hot-dip aluminum-coated steel wire having a lot of portions where plating films were not formed on its surface was obtained. It can be seen from the fact that the hot-dip aluminum-coated steel wire is wrong in stability of a plating film.

INDUSTRIAL APPLICABILITY

[0094] The hot-dip aluminum-coated steel wire obtained by the method for producing a hot-dip aluminum-coated steel wire according to the present invention can be suitably used in, for example, a wire harness of automobiles.

DESCRIPTION OF SYMBOLS

[0095]

- 1: molten aluminum
- 2: steel wire
- 3: hot-dip aluminum-coated steel wire
- 4: delivery device
- 5: plating bath
- 6: dipping area of a steel wire
- 7: steel wire-introducing device
- 8: through hole
- 9: tubular body
- 9a: dipping region of tubular body
- 9b: introducing port of tubular body
- 9c: opening part of introducing hole of tubular body
- 9d: discharge port of tubular body
- 9e: opening part of discharge port of tubular body
- 10: surface of molten aluminum
- 11: stabilizing member
- 11a: heat-resistant cloth of stabilizing member
- 12: nozzle
- 12a: tip end of nozzle
- 13: inert gas providing apparatus
- 14: pipe
- 15: cooling device
- 16: winding device
- 17: heating device
- 18: plating film
- 19: device for measuring diameter
- 19a: light emitting unit of device for measuring diameter
- 19b: light receiving unit of a device for measuring a diameter
- 19c: pulley of a device for measuring a diameter
- 19d: pulley of a device for measuring a diameter

Claims

1. A method for producing a hot-dip aluminum-coated steel wire by dipping a steel wire in molten aluminum, and then continuously drawing up the steel wire from the molten aluminum, to produce a hot-dip aluminum-coated steel wire, comprising:

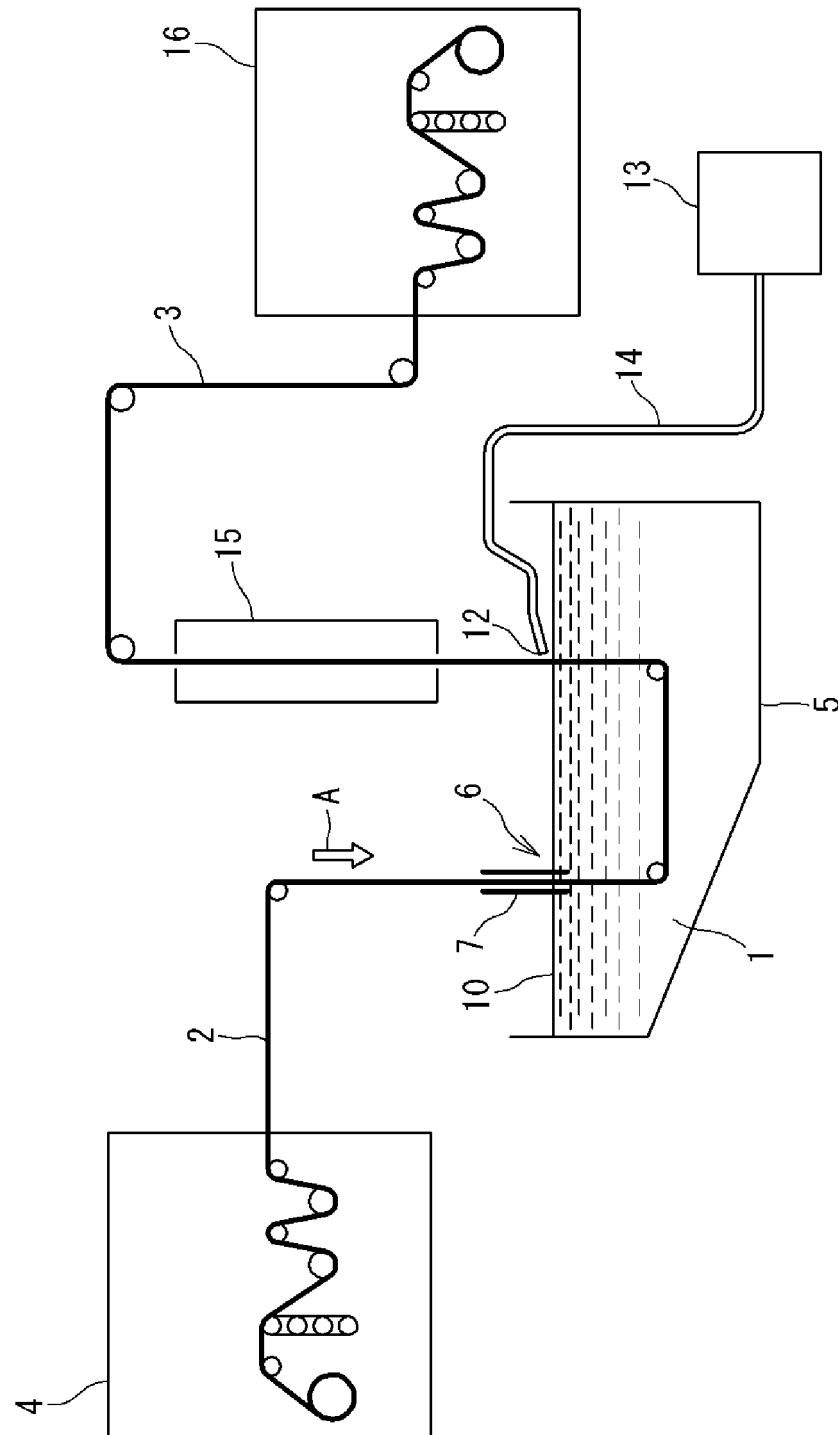
introducing a steel wire into a steel wire-introducing device comprising a tubular body of 10 mm to 1000 mm in total length having a through hole for introducing a steel wire into the tubular body, and a dipping region of 2

mm to 400 mm in length from one end part of the tubular body in a longitudinal direction of the tubular body for dipping the dipping region in the molten aluminum, wherein a value of the ratio of an area of the opening part of the through hole to an area of the cross section of the steel wire which is used in hot-dip aluminum plating [area of the opening part of the through hole of the tubular body/area of the cross section of the steel wire] is 3 to 4000, under a condition that the dipping region of the steel wire-introducing device is dipped in the molten aluminum, and thereafter dipping the steel wire in the molten aluminum.

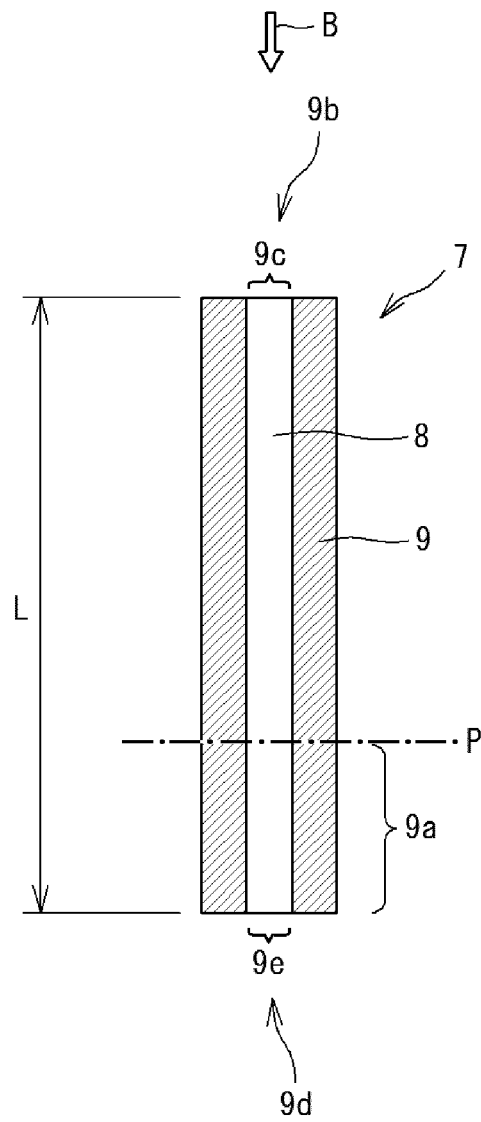
2. The method for producing a hot-dip aluminum-coated steel wire according to claim 1, wherein the steel wire is a steel wire made of stainless steel or carbon steel.

3. A steel wire-introducing device used in a dipping area of a steel wire where the steel wire is dipped in molten aluminum when a hot-dip aluminum-coated steel wire is produced by dipping the steel wire in the molten aluminum, and then continuously drawing up the steel wire from the molten aluminum, comprising a tubular body of 10 mm to 1000 mm in total length having a through hole for introducing a steel wire into the tubular body, and a dipping region of 2 mm to 400 mm in length from one end part of the tubular body in a longitudinal direction of the tubular body for dipping the dipping region in the molten aluminum, wherein a value of the ratio of an area of the opening part of the through hole to an area of the cross section of the steel wire which is used in hot-dip aluminum plating [area of the opening part of the through hole of the tubular body/area of the cross section of the steel wire] is 3 to 4000.

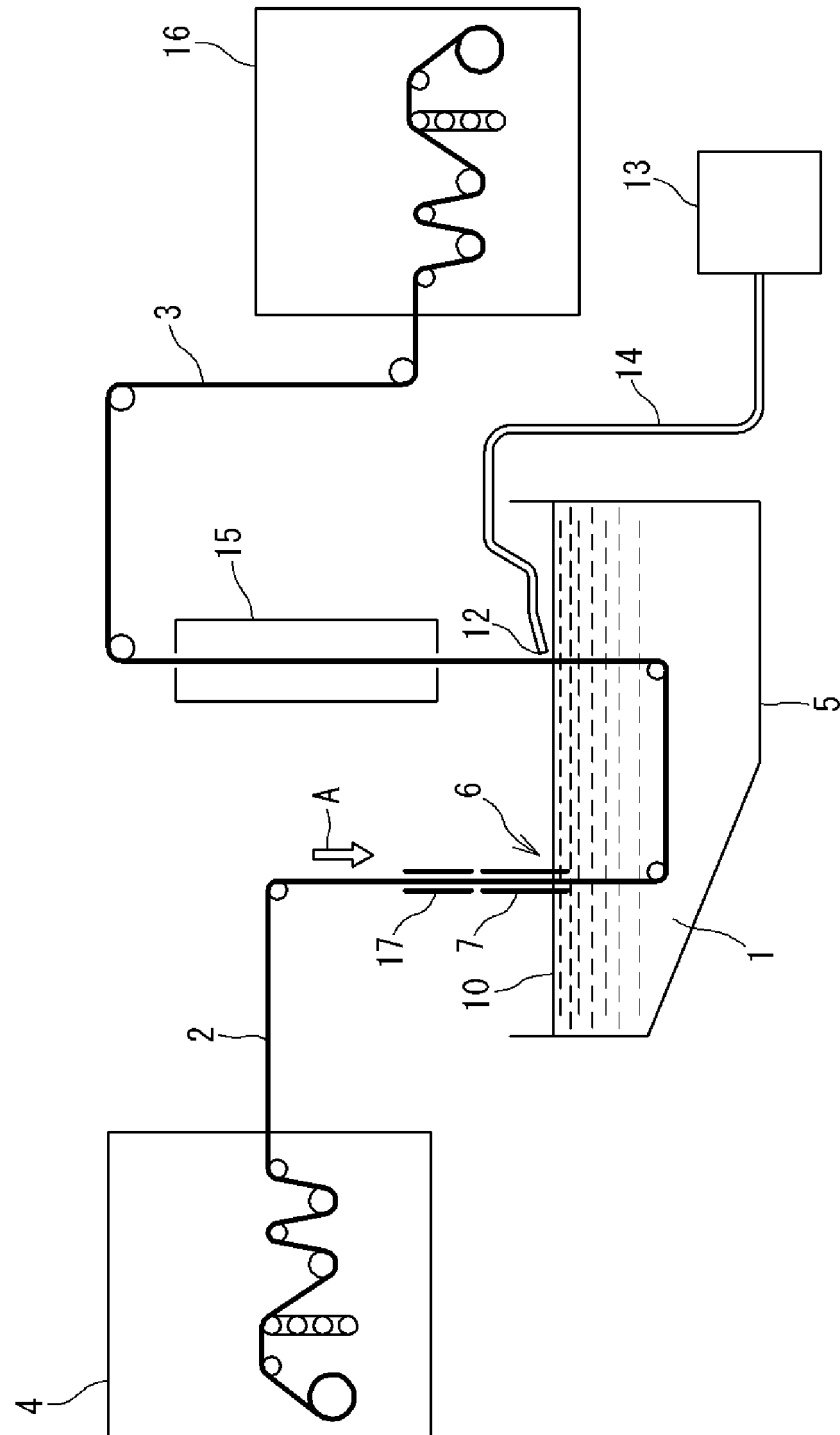
[Fig. 1]



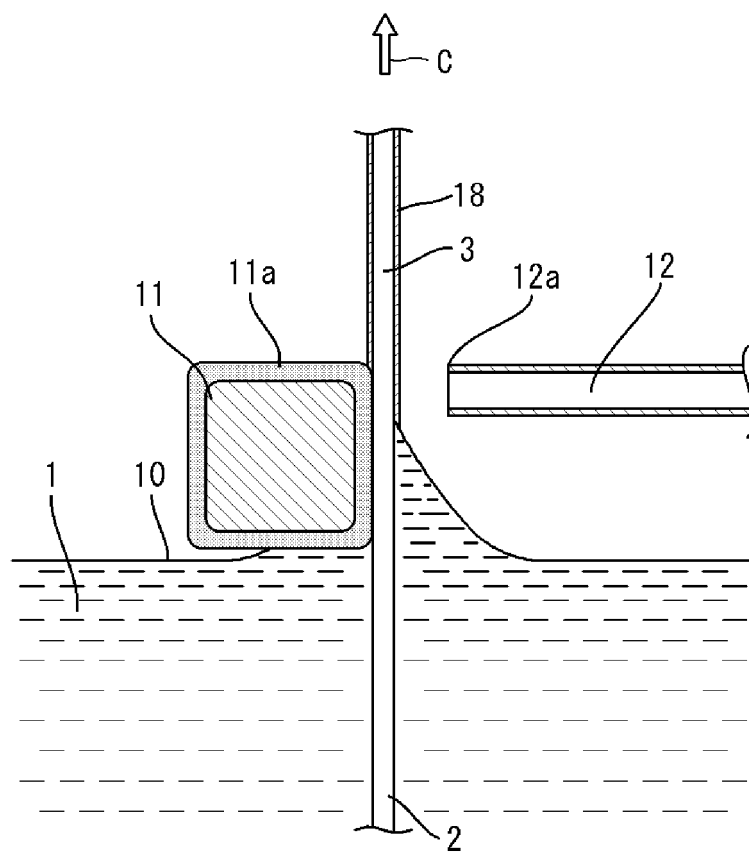
[Fig. 2]



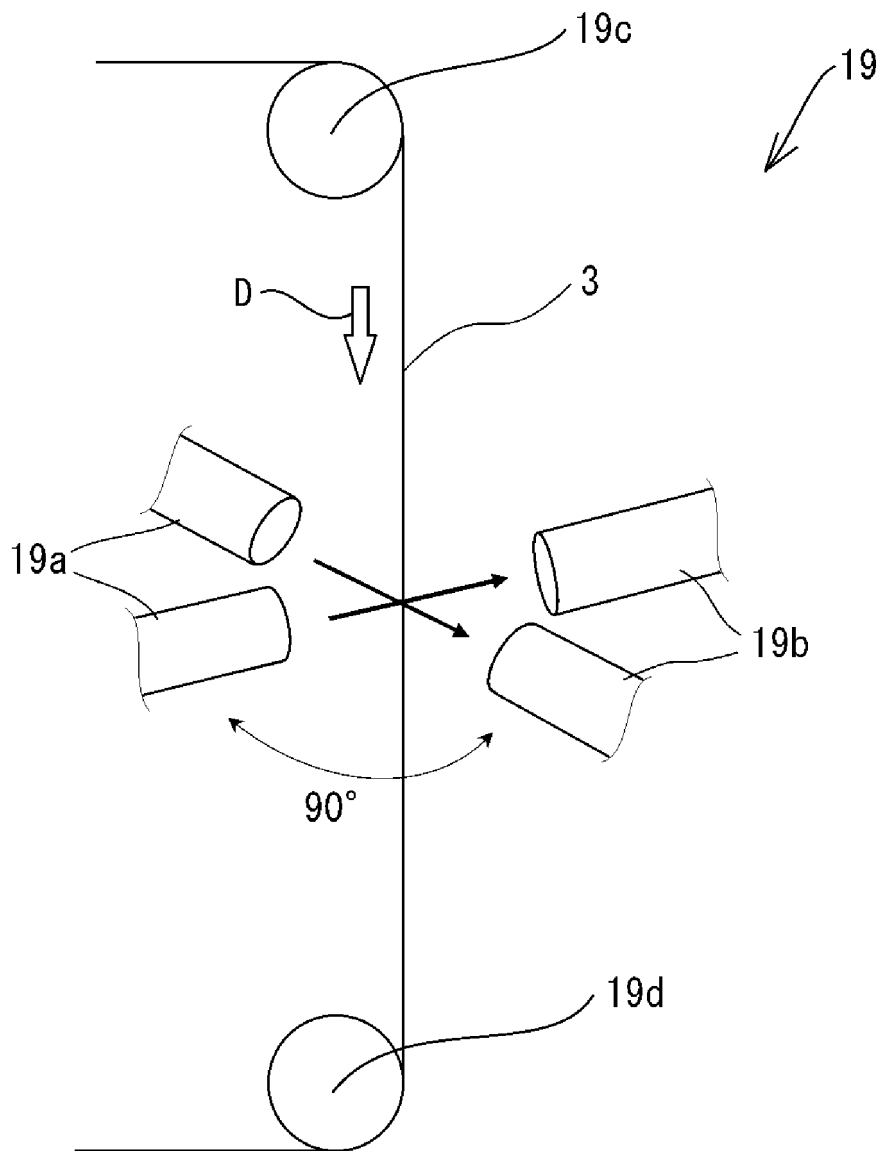
[Fig. 3]



[Fig. 4]



[Fig. 5]



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2017/009036

A. CLASSIFICATION OF SUBJECT MATTER

C23C2/38 (2006.01) i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C23C2/38

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

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2017
 Kokai Jitsuyo Shinan Koho 1971-2017 Toroku Jitsuyo Shinan Koho 1994-2017

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 11-209861 A (Hitachi Cable Ltd.), 03 August 1999 (03.08.1999), paragraphs [0001], [0013] to [0030]; fig. 1 (Family: none)	1, 3 2
Y	JP 2015-193877 A (Nisshin Steel Co., Ltd.), 05 November 2015 (05.11.2015), paragraph [0019] (Family: none)	2

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

* Special categories of cited documents:

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Date of the actual completion of the international search
27 March 2017 (27.03.17)Date of mailing of the international search report
04 April 2017 (04.04.17)Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2014185355 A [0005]