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(54) **METHOD FOR PRODUCING HOT-DIP ALUMINUM-COATED STEEL WIRE**

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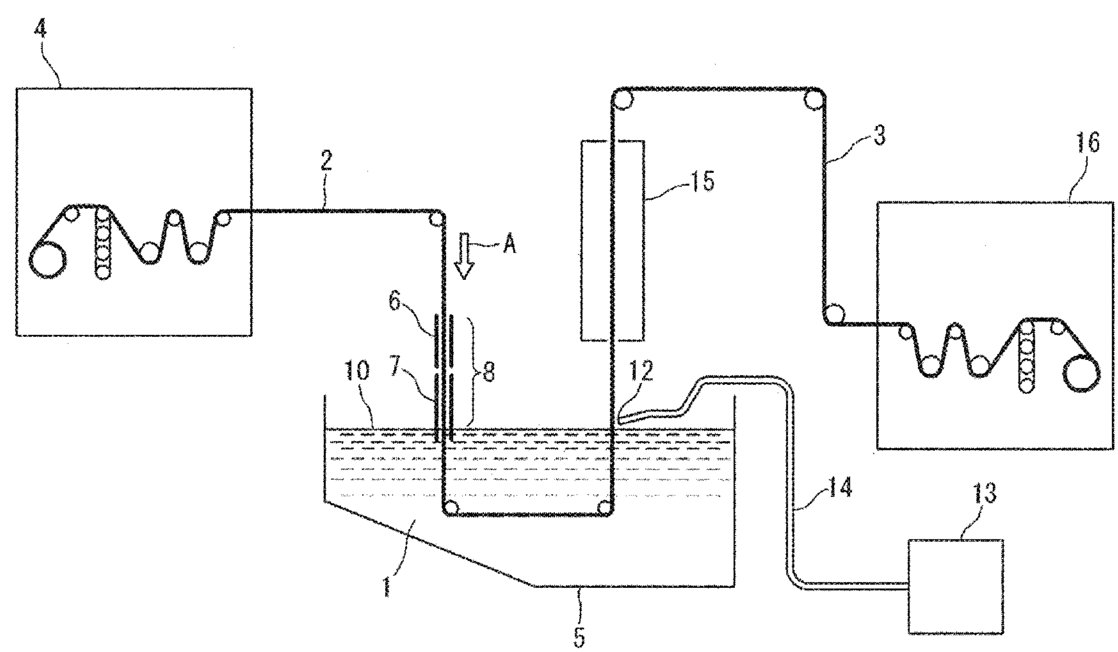
(57) **ABSTRACT**

A production method for molten-aluminum-plated copper wire, the production method being characterized by use of a heating device (**6**) that is for heating a copper wire (**2**) before the copper wire (**2**) is immersed in a molten aluminum plating bath (**1**) and of a bath surface control device (**7**) that comprises a tube-shaped body (**9**), which has a through hole (**9***a*) for passing the copper wire (**2**) through the inside thereof, and includes an immersion region (**9***b*) that is for immersion in the molten aluminum plating bath (**1**) from an end part of one end of the tube-shaped body (**9**) along the long direction of the tube-shaped body (**9**). The production method is also characterized in that the copper wire (**2**) is passed, in order, through the heating device (**6**) and the bath surface control device (**7**) and immersed in the molten aluminum plating bath (**1**) while the immersion region (**9***b*) of the bath surface control device (**7**) is immersed in the molten aluminum plating bath (**1**).



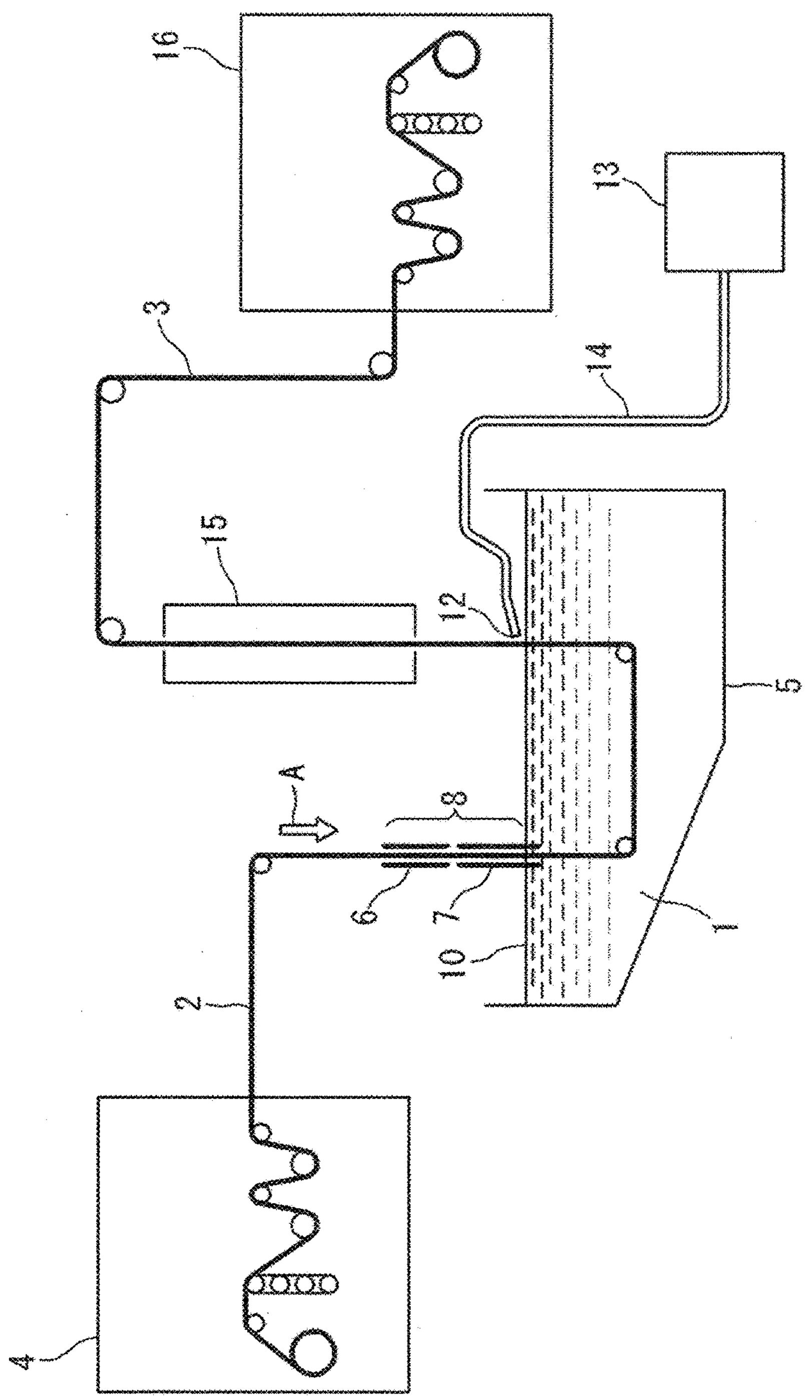


FIG. 1

FIG. 2

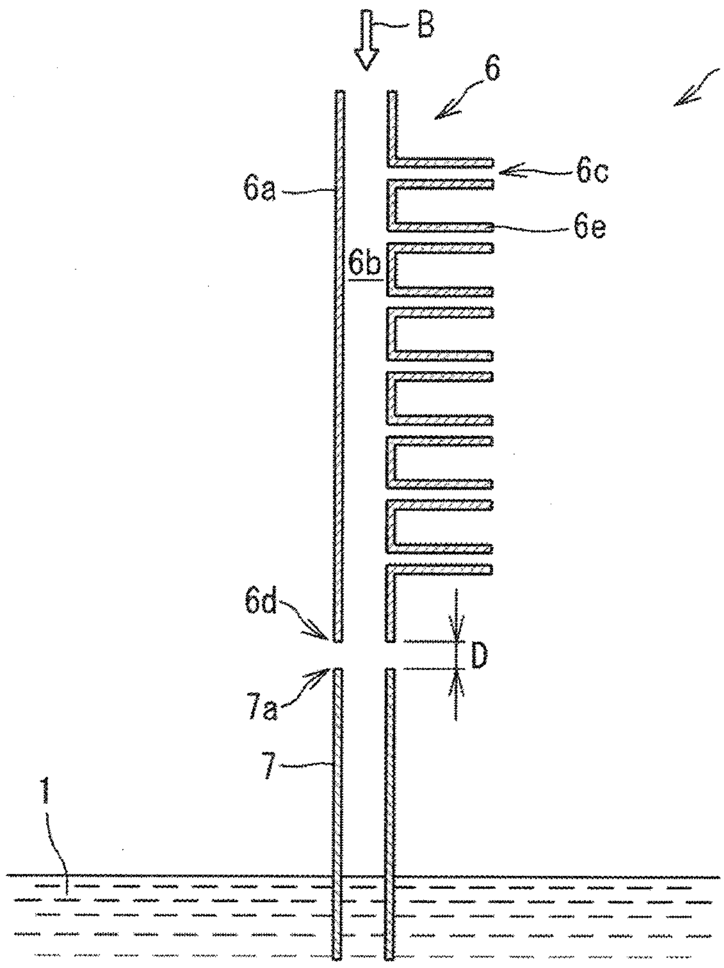


FIG. 3

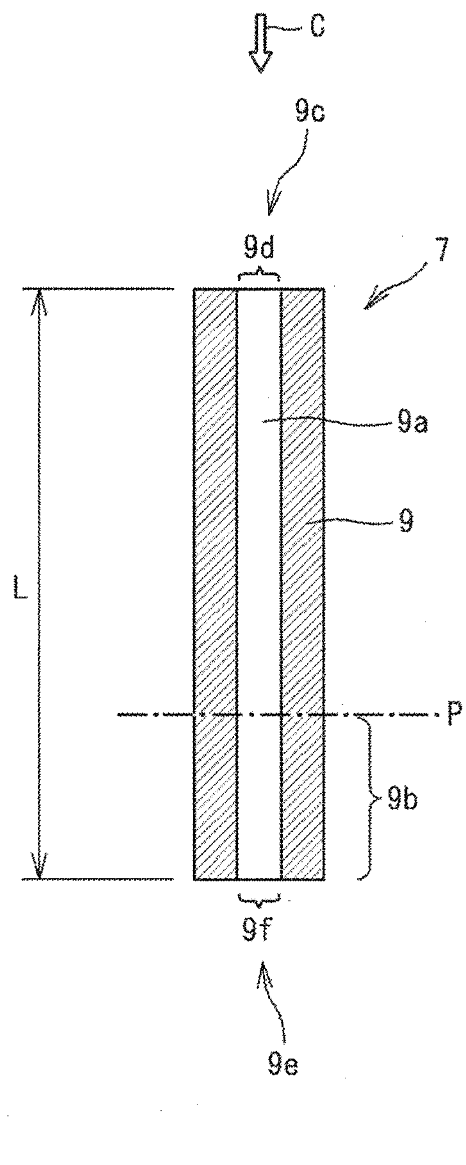


FIG. 4

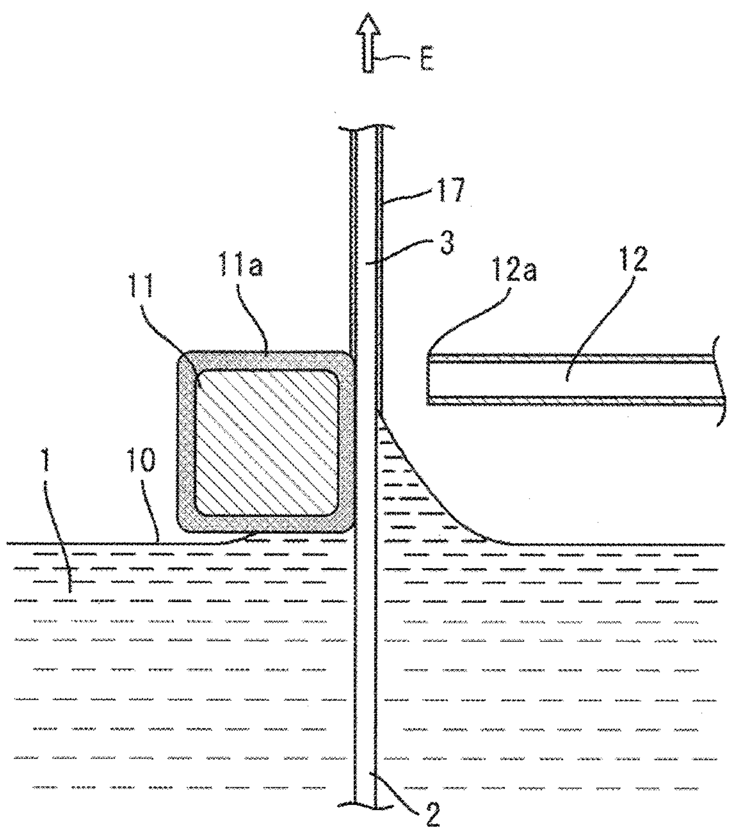


FIG. 5

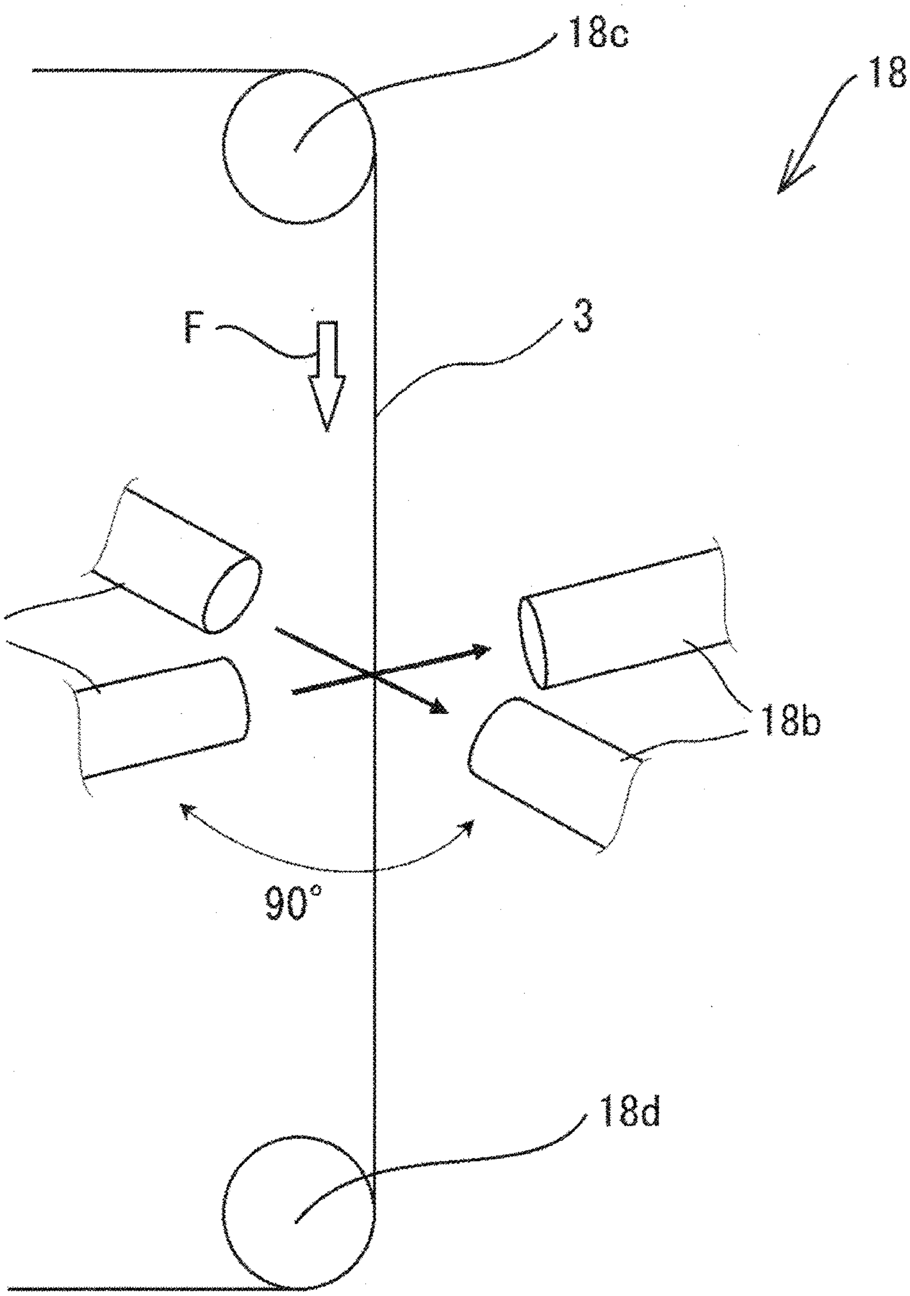
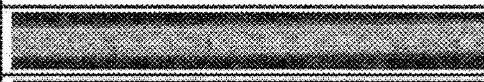
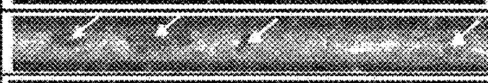
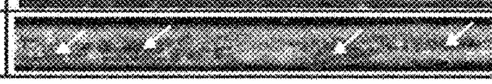


FIG. 6

Ex. and Com. Ex. No.	Preheating of steel wire	Line speed (m/min)	Outer appearance of steel wire
Ex. 2	Employed	300	
Ex. 7		400	
Comp. Ex. 1	Not employed	200	
Comp. Ex.2		400	

0.5 mm

METHOD FOR PRODUCING HOT-DIP ALUMINUM-COATED STEEL WIRE

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 controller for introducing a steel wire to hot-dip aluminum, 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 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] In recent years, it has been desired that a steel wire is dipped in molten aluminum at a high speed of 200 m/min or more in order to efficiently produce a hot-dip aluminum-coated steel wire. However, according to the above-mentioned process, when the starting wire is a steel wire or a 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 even when a steel wire is dipped in molten aluminum at a high speed of 200 m/min or more, and a controller for introducing a steel wire to hot-dip aluminum, 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 the steps of:

[0009] using a heating device for heating a steel wire prior to dipping of the steel wire in molten aluminum, and a liquid surface-controlling device including a tubular body having a through hole for introducing the steel wire into the tubular body, wherein the tubular body has a dipping region for dipping the tubular body in the molten aluminum from one end part of the tubular body along a longitudinal direction of the tubular body;

[0010] introducing the steel wire into the heating device and the liquid surface-controlling device sequentially under a condition that the dipping region of the liquid surface-controlling device is dipped in the molten aluminum; and

[0011] 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 controller for introducing a steel wire to hot-dip aluminum, used in 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, which includes

a heating device for heating a steel wire prior to dipping of the steel wire in molten aluminum, and

a liquid surface-controlling device including a tubular body having a through hole for introducing a steel wire into the tubular body, wherein the tubular body has a dipping region for dipping the tubular body in the molten aluminum from one end part of the tubular body along a longitudinal direction of the tubular body.

Effects of the Invention

[0012] According to the method for producing a hot-dip aluminum-coated steel wire and the liquid surface-controlling device of the present invention, there can be exhibited excellent effects such that a hot-dip aluminum-coated steel wire having a plating film over the whole surface can be efficiently produced even when a steel wire is dipped in molten aluminum at a high speed of 200 m/min or more.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] 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.

[0014] FIG. **2** is a schematic cross-sectional view showing one embodiment of a heating device used in a controller for introducing a steel wire to hot-dip aluminum according to the present invention.

[0015] FIG. **3** is a schematic cross-sectional view showing one embodiment of a liquid surface-controlling device used in a controller for introducing a steel wire to hot-dip aluminum according to the present invention.

[0016] 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.

[0017] 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.

[0018] FIG. **6** is a photograph substituted for a drawing, showing appearance of a hot-dip aluminum-coated steel wire obtained in Example 2, Example 7 and Comparative Examples 1 and 2.

MODE FOR CARRYING OUT THE INVENTION

[0019] The method for producing a hot-dip aluminum-coated steel wire according to 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 using a heating device for heating a steel wire prior to dipping of the steel wire in molten aluminum, and a liquid surface-controlling device including a tubular body having a through hole for introducing the steel wire into the tubular body, wherein the tubular body has a dipping region for dipping the tubular body in the molten aluminum from one end part of the tubular body along a longitudinal direction of the tubular body; introducing the steel wire into the heating device and the liquid surface-controlling device sequentially under a condition that the dipping region of the liquid surface-controlling device is dipped in the molten aluminum; and dipping the steel wire in the molten aluminum, as mentioned above.

[0020] 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 even when a steel wire is dipped in molten aluminum at a high speed of 200 m/min or more since the above-mentioned processes are employed in the method.

[0021] In addition, when a hot-dip aluminum-coated steel wire is produced by using the liquid surface-controlling device included in 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.

[0022] In addition, the steel wire can be introduced into the molten aluminum under the condition that the temperature of the steel wire is increased since the steel wire is introduced into the heating device included in the steel wire-introducing device of the present invention in advance of introduction of the steel wire into the liquid surface-controlling device. Accordingly, reactivity of the steel wire with the molten aluminum is 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 even when a line speed of the steel wire is increased.

[0023] 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.

[0024] 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.

[0025] 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**.

[0026] 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.

[0027] 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.

[0028] 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.

[0029] 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**.

[0030] 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.

[0031] 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.

[0032] 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.

[0033] 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**.

[0034] 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**.

[0035] 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**.

[0036] 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.

[0037] Incidentally, an element such as nickel, chrome, zinc, copper or iron is possibly inevitably incorporated in the molten aluminum **1**.

[0038] According to the present invention, the steel wire **2** is passed through a controller **8** for introducing a steel wire to hot-dip aluminum, which has a heating device **6** for heating the steel wire **2** prior to dipping of the steel wire **2** in the molten aluminum **1**, and a liquid surface-controlling device **7**. Since the present invention employs the above processes, a hot-dip aluminum-coated steel wire **3** having a plating film over the whole surface can be efficiently produced even when a steel wire is dipped in molten aluminum at a high speed of 200 m/min or more.

[0039] The heating device **6** used in the controller **8** for introducing a steel wire to hot-dip aluminum 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 heating device **6** used in the controller **8** for introducing a steel wire to hot-dip aluminum according to the present invention shown in FIG. **1**.

[0040] As shown in FIG. **2**, the heating device **6** has a heating device body **6*a*** having a cylindrical shape, made of, for example, stainless steel. An inside **6*b*** of the heating device body **6*a*** is vacant in order to pass through the steel wire **2** in a direction of arrow B. A branch pipe **6*e*** having a heating gas inlet **6*c*** for introducing a heating gas is provided at the side surface of the heating device body **6*a***.

[0041] The heating gas which is introduced into the heating device **6** 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 oxidization of the molten aluminum **1** existing in the liquid surface-controlling device **7** by ventilating the heating gas exhausted from the lower end **6*d*** of the heating device **6** to an introducing port equipped at the upper end **7*a*** of the liquid surface-controlling device **7** which is provided below the heating device **6**, to make the inside of the liquid surface-controlling 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.

[0042] The heating temperature of the steel wire **2** is preferably 60° C. or higher, more preferably 80° C. or higher, furthermore preferably 150° C. or higher, and still more preferably 200° 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 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 upper limit of the heating temperature cannot be absolutely determined because the upper limit of the heating temperature differs depending on the kind of the steel wire **2** and the like. It is preferred that the upper limit of the heating temperature is usually preferably 1000° C. or lower, more preferably 900° C. or lower, and furthermore preferably 800° C. or lower, in consideration of energy efficiency. Incidentally, the above-mentioned heating temperature is a temperature determined in accordance with a method as described in the following working examples.

[0043] The upper limit of a line speed of the steel wire **2** is not particularly limited, and is preferably 1000 m/min or lower, and more preferably 800 mm/min or lower, from the viewpoint of efficient production of the hot-dip aluminum-coated steel wire **3** having a plating film over the whole surface.

[0044] The length of the heating device body **6***a* shown FIG. **2** can be a length in which the steel wire **2** is heated to a predetermined temperature, and is not particularly limited. As one example of the length thereof, for example, the length can be 1 to 5 m or so. In addition, it is preferred that a diameter of the inside **6***b* of the heating device body **6***a* is appropriately adjusted in accordance with the diameter and kind of the steel wire **2** being used and the like, because the diameter of the inside **6***b* differs depending on the diameter and kind of the steel wire **2** being used. The diameter of the inside **6***b* of the heating device body **6***a* can be usually appropriately selected from a range of about 1.5 times to about 50 times of the diameter of the steel wire **2** in accordance with the diameter of the steel wire **2**. As one example of the diameter of the inside **6***b* of the heating device body **6***a*, it is preferred that the diameter of the inside **6***b* of the heating device body **6***a* is, for example, 0.3 mm to 10 mm or so when the steel wire **2** having a diameter of 0.2 mm is used.

[0045] The branch pipe **6***e* having the heating gas inlet **6***c* is provided on the side surface of the heating device body **6***a*. The steel wire **2** passing through the heating device **6** can be heated by introducing the heating gas into the heating gas inlet **6***c* of the branch pipe **6***e*. Alternatively, the steel wire **2** can be heated by providing a heater (not shown in the figure) inside the branch pipe **6***e*, and heating the heating gas passing through the branch pipe **6***e* with the heater.

[0046] In the embodiment shown in FIG. **2**, seven branch pipes **6***e* are provided. However, the number of the branch pipe **6***e* is not particularly limited, and the number of the branch pipe **6***e* can be only one, or can be 2 to 10.

[0047] In the embodiment shown in FIG. **2**, a gap D is provided between a lower end **6***d* of the heating device **6** and an upper end **7***a* of the liquid surface-controlling device **7** provided below the heating device **6**. It is preferred that the above-mentioned gap D is 3 mm or more from the viewpoint of efficient discharge of the heating gas from the gap D, and that the gap D is 10 mm or less when an inert gas is used as the heating gas, and the inside of the liquid surface-controlling device **7** is controlled to be an inert gas atmosphere. Incidentally, there is no necessity that the above-mentioned gap D is always provided. The heating device **6** can be separately produced from the liquid surface-controlling device **7**, and the heating device **6** and the liquid surface-controlling device **7** can be united into one body by, for example, screw mating and the like. When the heating device **6** and the liquid surface-controlling device **7** are united into one body, an exhaust port (not shown in the figure) for exhausting the heating gas, which is passed through the inside of the heating device **6**, can be provided on the side surface of the heating device **6** or the liquid surface-controlling device **7** as occasion demands.

[0048] Incidentally, a heating device such as an electric heating device or an induction heating device can be used in place of the heating device **6** in the present invention.

[0049] Next, the liquid surface-controlling device **7** which is used in the controller **8** for introducing a steel wire to the hot-dip aluminum is described on the basis of FIG. **3**. FIG. **3** is a schematic cross-sectional view showing one embodiment of the liquid surface-controlling device **7** used in the controller for introducing a steel wire to the hot-dip aluminum **8** according to the present invention.

[0050] As shown in FIG. **3**, the liquid surface-controlling device **7** includes a tubular body **9** having a through hole **9***a* for introducing the steel wire **2** into the tubular body **9**. The tubular body **9** has a dipping region **9***b* for dipping the tubular body **9** in the molten aluminum **1** from one end part of the tubular body which is to be dipped in the molten aluminum **1** to a virtual lime P along a longitudinal direction of the tubular body **9**.

[0051] The total length L of the liquid surface-controlling device **7** is preferably 30 mm or more, more preferably 40 mm or more, 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 **9***c* for introducing the steel wire **2** when the dipping region **9***b* 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 **9***a* of the tubular body **9**. The total length L of the liquid surface-controlling device **7** is preferably 500 mm or less, more preferably 300 mm or less, and 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.

[0052] The length of the dipping region **9***b* is preferably 2 mm or more, more preferably 5 mm or more, and furthermore 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 **9***b* is preferably 20 mm or less, and more preferably 15 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.

[0053] The length of the tubular body **9** along 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 **9***c* 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 **9***a* of the tubular body **9**.

[0054] A value of a ratio of an area of the opening part of the through hole **9***a* 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 **9***a* of the tubular body **9**/area of the cross section of the steel wire **2**] is preferably 3 or more from the viewpoint of smooth introduction of the steel wire **2** into the through hole **9***a* 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 value of the ratio is preferably 4000 or less, more preferably 3000 or less, furthermore preferably 2000 or less, and still more 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.

[0055] The shape of the opening part of the through hole **9***a* 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 **9***a* of the tubular body **9** and the steel wire **2** is preferably 10 μm or more, more preferably 20 μm or more, furthermore preferably 50 μm or more, and still more preferably 100 μm or more, from the viewpoint of avoidance of sliding of an inner wall of the through hole **9***a* of the tubular body **9** and the steel wire **2**.

[0056] Incidentally, the opening parts of the through hole **9***a* provided in the tubular body **9** are an opening part **9***d* provided at the introducing port **9***c* for introducing the steel wire **2** from one end of the tubular body **9**, and an opening part **9***f* provided at a discharge port **9***e* for discharging the steel wire **2** from another end of the tubular body **9** as shown in FIG. **3**. The area and shape of the opening part **9***d* can be the same as those of the opening part **9***f* Alternatively, the area and shape of the opening part **9***d* can be different from those of the opening part **9***f* However, it is preferred that the area and shape of the opening part **9***d* is the same as those of the opening part **9***f*, respectively, as shown in FIG. **3** from the viewpoint that the steel wire **2** is smoothly passed through the through hole **9***a* of the tubular body **9**, that sliding of the inner wall of the through hole **9***a* 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.

[0057] The steel wire **2** is introduced to the introducing port **9***c* of the tubular body **9** which constructs the liquid surface-controlling device **7** shown in FIG. **3**. The steel wire **2** is taken out from the discharge port **9***e*, and dipped in the molten aluminum **1**.

[0058] Next, 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.

[0059] When the steel wire **2** is drawn up from the molten aluminum **1** in the direction of arrow E 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**.

[0060] Incidentally, FIG. **4** is a schematic explanatory view showing the boundary 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.

[0061] The stabilization member **11** includes, for example, a square rod made of stainless steel, in which a heat-resistant cloth **11***a* is wound around the surface of the square rod, and the like. The heat-resistant cloth **11***a* 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 **11***a* 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**.

[0062] 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 of the steel wire **2** in contact of the steel wire **2** with the stabilization member **11**. Thereby a plating film **17** 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**.

[0063] In the embodiments illustrated in FIG. **1**, 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 addition, in the embodiment illustrated in FIG. **4**, a tip end **12***a* of a nozzle **12** is provided so that an inert gas is blown from the tip end **12***a* to the boundary between the steel wire **2** and the surface **10** of the molten aluminum **1**.

[0064] 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 **12***a* of the nozzle **12**, the temperature of the inert gas discharged from the tip end **12***a* of the nozzle **12**, an inner diameter of the tip end **12***a* of the nozzle **12**, and a volume flow rate discharged from the nozzle **12**.

[0065] The distance (the shortest distance) from the steel wire **2** to the tip end **12***a* of the nozzle **12** is preferably 1 mm or more from the viewpoint of avoidance of a contact of the tip end **12***a* 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 **12***a* of the nozzle **12** is preferably 50 mm or less, more preferably 40 mm or less, furthermore preferably 30 mm or less, and still more 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.

[0066] The inside diameter of the tip end **12***a* 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 **12***a* of the nozzle **12** to the boundary between the steel wire **2** and the surface **10** of the molten aluminum **1**. The inside diameter of the tip end **12***a* 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.

[0067] The inert gas can be provided, for example, from an inert gas providing apparatus **13** shown in FIG. **1** through a pipe **14** to the nozzle **12**. 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.

[0068] 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.

[0069] In FIG. **4**, the volume flow rate of the inert gas discharged from the tip end **12***a* 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**.

[0070] The temperature of the inert gas discharged from the tip end **12***a* 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 **12***a* 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 **12***a* of the nozzle **12** in a distance of 2 mm.

[0071] The line speed in 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 line 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 **17** formed on the surface of the hot-dip aluminum-coated steel wire **3** can be appropriately controlled by adjusting the line speed.

[0072] In the present invention, even when the line speed of 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 **17** 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 **17** formed over the whole surface can be efficiently produced.

[0073] Incidentally, a cooling device **15** can be provided above the nozzle **12** as occasion demands as illustrated in FIG. **1** 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 **17** 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**.

[0074] 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 as shown in FIG. **1**.

[0075] 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 crimpling process, and increase in mechanical strength per unit outer diameter of the hot-dip aluminum-coated steel wire **3**.

[0076] 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.

[0077] The hot-dip aluminum-coated steel wire **3** obtained in the present invention can be suitably used, for example, in a wire harness of an automobile, and the like.

Examples

[0078] 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.

[0079] A hot-dip aluminum-coated steel wire was produced based on the embodiment as illustrated in FIG. **1**.

[0080] As a steel wire, a steel wire having a diameter shown in each table, and made of steel shown in each table was used. The term "37A" listed in the column of "kind" of "steel wire" in Table 2 and Table 3 means a steel wire made of high carbon steel containing 0.37% by mass of carbon.

[0081] 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.

[0082] The steel wire was heated at a heating temperature shown in each table by introducing the steel wire into a heating device, before the steel wire was introduced into a liquid surface-controlling device. As the heating device, a heating device having a heating device body of which inner diameter is 10 mm, and eight branch pipes in each of which a Kanthal® wire (not shown in the figure) wound in a coil shape was built. An introducing gas shown in each table was supplied to each branch pipe, to heat the introducing gas, and the heated introducing gas was introduced to the inside of the heating device body, to preheat the steel wire. 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.

[0083] As the liquid surface-controlling device, a liquid surface-controlling device **7** shown in FIG. **3**, which was produced by assembling blocks or square bars made of stainless steel, was used. The liquid surface-controlling device **7** had a total length L of 100 mm, and the shape, size and area of the opening part **9***d* of the introducing port **9***c* of the through hole **9***a* were the same as those of the opening part **9***f* of the discharge port **9***e* of the through hole **9***a*. The shape, size and area of the opening part of the through hole **9***a* of the liquid surface-controlling device **7**, and the value of the ratio of the area of the opening part of the through hole **9***a* of the tubular body **9** to the area of the cross section of the steel wire (referred to as "value of area ratio" in each table) were listed in each table. The dipping region **9***b* having a length of 10 mm from the lower end of the liquid surface-controlling device **7** was dipped in the molten aluminum, and the steel wire being introduced into the liquid surface-controlling device **7** was subsequently dipped in the molten aluminum.

[0084] 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 each table) was used. The steel wire was dipped in the molten aluminum at a temperature of the molten aluminum shown in each table at a line speed (speed of drawing up of steel wire) shown in each table, and then the steel wire was drawn up from the molten aluminum.

[0085] A nozzle having an inner diameter of 3 mm at the 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.

[0086] 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 each table. Incidentally, a method for determining the average thickness of the plating film is as follows:

[0087] [Method for Determining Average Thickness of Plating Film]

[0088] The average thickness of a plating film of a hot-dip aluminum-coated steel wire obtained in each example or each comparative example 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.

[0089] As a device **18** 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 **18** for measuring a diameter had a pair of a pulley **18***c* and a pulley **18***d* which were positioned in a vertical direction against the steel wire, and a pair of a light emitting unit **18***a* and a light receiving unit **18***b* which were arranged in a horizontal direction at a central position between the pulley **18***c* and the pulley **18***d*. The light emitting unit **18***a* and the light receiving unit **18***b* were arranged so that the light emitting unit **18***a* and the light receiving unit **18***b* were opposed to each other. The light emitting unit **18***a* and the light receiving unit **18***b* adjacent each other were arranged so that an angle between the light emitting unit **18***a* and the light receiving unit **18***b* was 90° as shown in FIG. **5**.

[0090] 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 F between the pulley **18***c* and the pulley **18***d*, 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 **18** for measuring a diameter. The number of measurement points of the outer diameter was adjusted to about 71000 points.

[0091] 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 each table) 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 each table.

[0092] [Stability of Plating Film]

[0093] 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 each table.

[0094] 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 (500 mm)].

[0095] 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:

[Non-plated rate]={[Non-plated length (mm)]/[Observed length (mm)]}×100. The stability of the plating film was evaluated in accordance with the following evaluation criteria.

[0096] (Evaluation Criteria of Stability of Plating Film).

5: Non-plated rate is less than 1% (pass).

4: Non-plated rate is 1% or more and less than 5% (pass).

3: Non-plated 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

	Steel wire		Hot-dip Al		Line	Heating device		Opening part of through hole of liquid surface-controlling device			Value	Average thickness of plating	Stability
Ex. No.	Diameter (mm)	Kind	Kind	Temp. (° C.)	speed (m/min)	Heating temp. (° C.)	Introducing gas	Shape	Size (mm)	Area (mm^2)	of area ratio	film (μm)	of plating film
Ex. 1	0.20	SUS304	8% Si	700	300	82	Nitrogen	Rectangle	0.25 × 3.0	0.75	24	5.9	3
Ex. 2	0.20	SUS304	8% Si	700	300	168	Nitrogen	Rectangle	0.25 × 3.0	0.75	24	6.0	4
Ex. 3	0.20	SUS304	8% Si	700	300	250	Nitrogen	Rectangle	0.25 × 3.0	0.75	24	5.8	5
Ex. 4	0.20	SUS304	8% Si	700	300	390	Nitrogen	Rectangle	0.25 × 3.0	0.75	24	5.7	5
Ex. 5	0.20	SUS304	8% Si	700	300	582	Nitrogen	Rectangle	0.25 × 3.0	0.75	24	6.1	5
Ex. 6	0.20	SUS804	8% Si	700	300	710	Nitrogen	Rectangle	0.25 × 3.0	0.75	24	5.8	5
Ex. 7	0.20	SUS304	8% Si	700	400	330	Nitrogen	Rectangle	0.25 × 3.0	0.75	24	6.4	5
Ex. 8	0.20	SUS304	8% Si	700	300	330	Nitrogen	Round	φ2.0	3.14	100	5.9	5
Ex. 9	0.20	SUS304	8% Si	685	300	390	Nitrogen	Rectangle	0.8 × 3.0	2.4	76	6.2	5
Ex. 10	0.20	SUS304	8% Si	720	300	390	Nitrogen	Rectangle	0.8 × 3.0	2.4	76	5.6	5
Ex. 11	0.20	SUS304	8% Si	685	300	390	Nitrogen	Rectangle	0.8 × 3.0	2.4	76	5.5	5
Ex. 12	0.20	SUS304	8% Si	700	300	390	Nitrogen	Rectangle	0.31 × 0.31	0.096	3.1	4.4	5
Ex. 13	0.20	SUS304	8% Si	700	300	390	Nitrogen	Round	φ0.35	0.096	3.1	4.5	5
Ex. 14	0.07	SUS304	8% Si	700	600	322	Nitrogen	Rectangle	1.0 × 2.0	2.0	520	4.8	5
Ex. 15	0.10	SUS304	8% Si	700	600	333	Nitrogen	Rectangle	1.0 × 2.0	2.0	255	5.2	5
Comp. Ex. 1	0.20	SUS304	8% Si	700	200	32	Nitrogen	Rectangle	0.25 × 3.0	0.75	24	5.5	2
Comp. Ex. 2	0.20	SUS304	8% Si	700	400	32	Nitrogen	Rectangle	0.25 × 3.0	0.75	24	5.8	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].

TABLE 2

	Steel wire		Hot-dip Al		Line	Heating device		Opening part of through hole of liquid surface-controlling device			Value	Average thickness of plating	Stability
Ex. No.	Diameter (mm)	Kind	Kind	Temp. (° C.)	speed (m/min)	Heating temp. (° C.)	Introducing gas	Shape	Size (mm)	Area (mm^2)	of area ratio	film (μm)	of plating film
Ex. 16	0.15	SUS304	8% Si	700	200	315	Nitrogen	Rectangle	1.0 × 2.0	2.0	113	5.3	5
Ex. 17	0.30	SUS304	8% Si	700	300	302	Nitrogen	Rectangle	2.0 × 3.0	6.0	85	9.3	5
Ex. 18	0.60	SUS304	8% Si	700	300	282	Nitrogen	Rectangle	2.0 × 3.0	6.0	21	12.3	5
Ex. 19	1.00	SUS304	8% Si	700	300	240	Nitrogen	Rectangle	2.0 × 3.0	6.0	8	14.9	5
Ex. 20	0.20	SUS430	8% Si	700	300	82	Nitrogen	Rectangle	0.25 × 3.0	0.75	24	5.9	3
Ex. 21	0.20	SUS430	8% Si	700	300	168	Nitrogen	Rectangle	0.25 × 3.0	0.75	24	6.0	4
Ex. 22	0.20	SUS430	8% Si	700	300	390	Nitrogen	Rectangle	0.25 × 3.0	0.75	24	5.8	5
Ex. 23	0.20	37A	8% Si	700	300	84	Nitrogen	Rectangle	0.25 × 3.0	0.75	24	5.9	3
Ex. 24	0.20	37A	8% Si	700	300	172	Nitrogen	Rectangle	0.25 × 3.0	0.75	24	6.1	4
Ex. 25	0.20	37A	8% Si	700	300	394	Nitrogen	Rectangle	0.25 × 3.0	0.75	24	5.7	5
Ex. 26	0.20	37A	8% Si	700	300	715	Nitrogen	Rectangle	0.25 × 3.0	0.75	24	6.2	5
Ex. 27	0.20	37A	8% Si	700	400	340	Nitrogen	Rectangle	0.25 × 3.0	0.75	24	5.4	5
Ex. 28	0.20	37A	8% Si	700	300	330	Nitrogen	Round	φ2.0	3.14	100	5.5	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 3

	Steel wire		Hot-dip Al		Line	Heating device		Opening part of through hole of liquid surface-controlling device			Value	Average thickness of plating	Stability
Ex. No.	Diameter (mm)	Kind	Kind	Temp. (° C.)	speed (m/min)	Heating temp. (° C.)	Introducing gas	Shape	Size (mm)	Area (mm^2)	of area ratio	film (μm)	of plating film
Ex. 29	0.20	SUS304	8% Si	700	300	167	Air	Rectangle	0.25 × 3.0	0.75	24	5.9	3
Ex. 30	0.20	SUS304	8% Si	700	300	330	Air	Rectangle	0.25 × 3.0	0.75	24	6.2	4
Comp. Ex. 3	0.20	SUS304	8% Si	700	300	32	Air	Rectangle	0.25 × 3.0	0.75	24	5.4	2
Ex. 31	0.20	37A	8% Si	700	300	170	Air	Rectangle	0.25 × 3.0	0.75	24	6.0	3
Ex. 32	0.20	37A	8% Si	700	300	331	Air	Rectangle	0.25 × 3.0	0.75	24	5.9	4

TABLE 3-continued

Ex. No.	Steel wire Diameter (mm)	Steel wire Kind	Hot-dip Al Kind	Hot-dip Al Temp. (° C.)	Line speed (m/min)	Heating device Heating temp. (° C.)	Heating device Introducing gas	Opening part of through hole of liquid surface-controlling device Shape	Opening part of through hole of liquid surface-controlling device Size (mm)	Opening part of through hole of liquid surface-controlling device Area (mm^2)	Value of area ratio	Average thickness of plating film (μm)	Stability of plating film
Comp. Ex. 4	0.20	37A	8% Si	700	300	34	Air	Rectangle	0.25 × 3.0	0.75	24	5.8	2

(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].

[0097] Each outer appearance of the hot-dip aluminum-coated steel wires obtained in Example 2, Example 7 and Comparative Examples 1-2 is shown in FIG. **6**. A white arrow shown in the figure denotes the area where a plating film was not formed (non-plating area) when the surface of the hot-dip aluminum-coated steel wire was observed. From the results shown in FIG. **6**, it can be seen that a hot-dip aluminum-coated steel wire having a plating film over the whole surface can be efficiently produced according to the above-mentioned working examples.

[0098] In addition, from the results shown in Table 3, it can be seen that a hot-dip aluminum-coated steel wire having a plating film over the whole surface can be efficiently produced even when air is used in place of nitrogen gas as a heating gas for preheating a steel wire prior to dipping of the steel wire in molten aluminum, according to the method for producing a hot-dip aluminum-coated steel wire of the present invention.

[0099] From the above results, according to a method for producing a hot-dip aluminum-coated steel wire according to each working example, 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, are exhibited even when a steel wire is dipped in molten aluminum at a high speed of 200 m/min or more.

INDUSTRIAL APPLICABILITY

[0100] 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

[0101] **1**: molten aluminum
[0102] **2**: steel wire
[0103] **3**: hot-dip aluminum-coated steel wire
[0104] **4**: delivery device
[0105] **5**: plating bath
[0106] **6**: heating device
[0107] **6***a*: heating device body
[0108] **6***b*: inside of heating device body
[0109] **6***c*: heating gas inlet of heating device body
[0110] **6***d*: lower end of heating device body
[0111] **6***e*: branch pipe of heating device body
[0112] **7**: liquid surface-controlling device
[0113] **7***a*: upper end of liquid surface-controlling device
[0114] **8**: controller for introducing a steel wire
[0115] **9**: tubular body
[0116] **9***a*: through hole of tubular body
[0117] **9***b*: dipping region of tubular body
[0118] **9***c*: introducing port of tubular body
[0119] **9***d*: opening part of introducing port of tubular body
[0120] **9***e*: discharge port of tubular body
[0121] **9***f* opening part of discharge port of tubular body
[0122] **10**: surface of molten aluminum
[0123] **11**: stabilizing member
[0124] **11***a*: heat-resistant cloth of stabilizing member
[0125] **12**: nozzle
[0126] **12***a*: tip end of nozzle
[0127] **13**: inert gas providing apparatus
[0128] **14**: pipe
[0129] **15**: cooling device
[0130] **16**: winding device
[0131] **17**: plating film
[0132] **18**: device for measuring a diameter of a steel wire by passing through a steel wire
[0133] **18***a*: light-emitting unit of a device for measuring diameter of a steel wire by passing through a steel wire
[0134] **18***b*: light receiving unit of a device for measuring a diameter of a steel wire by passing through a steel wire
[0135] **18***c*: pulley of a device for measuring a diameter of a steel wire by passing through a steel wire
[0136] **18***d*: pulley of a device for measuring a diameter of a steel wire by passing through a steel

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 the steps of:

using a heating device for heating a steel wire prior to dipping of the steel wire in molten aluminum, and a liquid surface-controlling device comprising a tubular body having a through hole for introducing the steel wire into the tubular body, wherein the tubular body has a dipping region for dipping the tubular body in the molten aluminum from one end part of the tubular body along a longitudinal direction of the tubular body;

introducing the steel wire into the heating device and the liquid surface-controlling device sequentially under a condition that the dipping region of the liquid surface-controlling device is dipped in the molten aluminum; and

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 controller for introducing a steel wire to hot-dip aluminum, used in 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, comprising:

a heating device for heating the steel wire prior to dipping of the steel wire in molten aluminum, and

a liquid surface-controlling device comprising a tubular body having a through hole for introducing the steel wire into the tubular body, wherein the tubular body has a dipping region for dipping the tubular body in the molten aluminum from one end part of the tubular body along a longitudinal direction of the tubular body.

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