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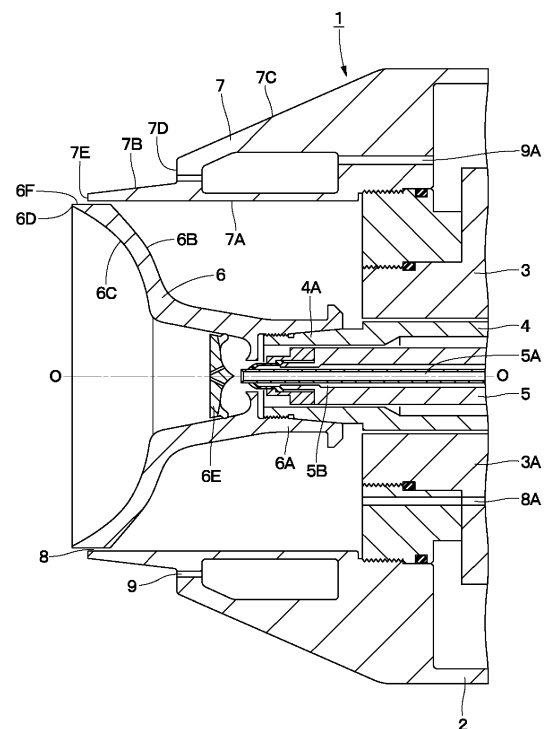
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(54) **ROTARY ATOMIZATION HEAD-TYPE COATING MACHINE AND ELECTROSTATIC COATING APPARATUS**

(57) [Solution] An inner cylinder surface 7A of a shaping air ring 7 is formed with a uniform inner diameter dimension. A first shaping air jet portion 8 is formed as an annular gap, and a gap dimension a thereof is set at 0.1-1.0 mm. A front end portion 7E of the shaping air ring 7 is disposed at a position 0.1-10.0 mm to the rear of a discharge edge 6D of a rotary atomization head 6. A radial width dimension c of the front end portion 7E is set at 2 mm or less. A front outer cylinder surface 7B of the shaping air ring 7 is such that a taper angle β opening out toward the rear is set at 25° or less in relation to an axis 0-0.

[Fig. 1]

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Description

[Technical Field]

- 5 **[0001]** The present invention relates to a rotary atomization head-type coating machine and to an electrostatic coating apparatus which are suitably used for painting motor vehicle bodies, for example.

[Background Art]

- 10 **[0002]** A rotary atomization head-type coating machine, which has good paint coating efficiency and provides a good paint finish, is generally used to paint motor vehicle bodies. The rotary atomization head-type coating machine comprises: an air motor powered by compressed air; a hollow rotary shaft which is rotatably supported while extending in a longitudinal direction along an axis of the air motor and has a front end portion protruding from the air motor; a feed tube extending through the inside of the rotary shaft as far as the front end portion of the rotary shaft; a rotary atomization head which is
 15 mounted on the front end portion of the rotary shaft and comprises an outer circumferential surface opening out into a cup shape, an inner circumferential surface for diffusing a paint supplied from the feed tube, and a discharge edge positioned at a front end for discharging paint; a cylindrical shaping air ring provided on an outer circumferential side of the rotary atomization head; a first shaping air jet portion which is provided on the outer circumferential side of the rotary atomization head and jets first shaping air toward paint discharged from the discharge edge; and a second shaping air jet portion which
 20 is positioned radially outside the first shaping air jet portion, is disposed surrounding the rotary atomization head, and jets second shaping air toward the paint discharged from the discharge edge (Patent Document 1).

- [0003]** Coating performed using the rotary atomization head-type coating machine is expected to achieve effects such as a reduction in the amount of paint which is used, due to better efficiency of coating an object being painted, a reduction in the amount of carbon dioxide emitted, due to simpler equipment such as a coating booth, and a reduction in the cost of
 25 maintenance of the coating booth.

[Prior Art Documents]

[Patent Documents]

- 30 **[0004]** [Patent Document 1] JP 2003-236417 A

[Summary of the Invention]

- 35 [Problems to be Solved by the Invention]

- [0005]** When coating is performed using the rotary atomization head-type coating machine, first shaping air is jetted from the first shaping air jet portion and second shaping air is jetted from the second shaping air jet portion toward paint particles discharged from the discharge edge of the rotary atomization head. As a result, the flow of paint particles sprayed from the
 40 atomization head is adjusted, and the paint particles are shaped into a spray pattern which produces a uniform film thickness distribution.

- [0006]** However, a coating distance from the rotary atomization head-type coating machine (rotary atomization head) to the object being coated is set to take account of preventing contact between the rotary atomization head and the object being coated, and of preventing soiling of the coating machine. There tends to be a reduction in straightness of the paint particles afforded by the shaping air at such a coating distance. Consequently, the paint particles are carried over a wide
 45 range by an air stream flowing over the surface of the object being coated and do not reach the object being coated (coating surface), which causes a drop in coating efficiency.

- [0007]** It would therefore be feasible to increase the flow rate of shaping air, but that would mean an increase in paint particles flowing along the surface of the object being coated. As a result, the paint particles discharged from the rotary atomization head would be affected by turbulence produced by the shaping air, inducing a turbulent flow so that the paint particles can no longer reach the object being coated and there is a reduction in coating efficiency.

- [0008]** There is also a method of shortening the coating distance as a measure for achieving high coating efficiency (referred to as close-up coating or proximity coating, etc.). This method makes it possible to improve the straightness of the paint particles conveyed by the shaping air, therefore enabling better coating efficiency. However, some of the paint
 55 particles sprayed from the rotary atomization head are affected by centrifugal force produced by rotation of the rotary atomization head and are ejected in the radial direction of the atomization head, the paint particles then being entrained in the turbulence of the shaping air jetted from behind the rotary atomization head, leading to a situation in which these paint particles can no longer reach the object being coated.

[0009] Based on the problems described above, in order to considerably reduce the amount of paint particles not reaching the object being coated, which causes a reduction in coating efficiency, it is firstly feasible to improve the straightness of the paint particles by shortening the coating distance, and secondly to change the coating conditions in order to reduce scattering of paint particles (for example, reducing the rotation speed of the rotary atomization head, reducing the flow rate of shaping air, reducing the flow rate of paint), etc.

[0010] First of all, shortening the coating distance improves the efficiency of coating the object being coated, but shaping air turbulence still remains, which is therefore a problem in that there is still a certain amount of paint particles scattered into the surrounding area and not reaching the object being coated.

[0011] Next, in terms of coating conditions for reducing scattering of paint particles, if the rotation speed of the rotary atomization head is reduced excessively, or the flow rate of shaping air is made excessively low, for example, then the particle size of the paint sprayed from the rotary atomization head tends to increase, and there is a reduction in coating (paint film) quality. The viscosity of the paint is reduced as a measure against this, in order to make the large-particle-diameter paint particles smaller. However, reducing the viscosity of the paint makes the paint film likely to drip, and it is very difficult to adjust the paint. Furthermore, reducing the flow rate of the paint leads to a reduction in the width of a paint spray pattern, and there is a problem of lower productivity per coating machine.

[0012] The present invention has been devised in light of the problems in the prior-art, and the objective of the present invention lies in providing a rotary atomization head-type coating machine and an electrostatic coating apparatus which are capable of achieving better coating efficiency.

[Means for Solving the Problems]

[0013] The present invention constitutes a rotary atomization head-type coating machine comprising: an air motor powered by compressed air; a hollow rotary shaft which is rotatably supported while extending in a longitudinal direction along an axis of the air motor and has a front end portion protruding from the air motor; a feed tube extending through the inside of the rotary shaft as far as the front end portion of the rotary shaft; a rotary atomization head which is mounted on the front end portion of the rotary shaft and comprises an outer circumferential surface opening out into a cup shape, an inner circumferential surface for diffusing a paint supplied from the feed tube, and a discharge edge positioned at a front end for discharging paint; a cylindrical shaping air ring provided on an outer circumferential side of the rotary atomization head; and a first shaping air jet portion which is provided on the outer circumferential side of the rotary atomization head and jets first shaping air toward paint discharged from the discharge edge, wherein an inner cylinder surface of the shaping air ring is such that at least a front side portion facing the outer circumferential surface of the rotary atomization head is formed with a uniform inner diameter dimension, the first shaping air jet portion is formed as an annular gap between the outer circumferential surface of the rotary atomization head and the inner cylinder surface of the shaping air ring, a radial dimension of the gap between the outer circumferential surface of the rotary atomization head and the inner cylinder surface of the shaping air ring is set at 0.1-1.0 mm, a front end portion of the shaping air ring is disposed at a position 0.1-10.0 mm to the rear of the discharge edge of the rotary atomization head, a radial width dimension of the front end portion of the shaping air ring is set at 2 mm or less, and an outer cylinder surface of the shaping air ring is such that a taper angle opening out from the front end portion of the shaping air ring toward the rear is set at 25° or less in relation to the axis.

[Effects of the Invention]

[0014] The present invention enables better coating efficiency.

[Brief Description of the Drawings]

[0015]

[Fig. 1] is a view in cross section showing a rotary atomization head-type coating machine according to a first embodiment of the present invention.

[Fig. 2] is a view in cross section showing an enlargement of dimensions of each part.

[Fig. 3] is an explanatory diagram illustrating a flow of air when a width dimension of a front end portion of the shaping air ring is set at 2 mm or less.

[Fig. 4] is an explanatory diagram illustrating, as a comparative example, the flow of air when the width dimension of the front end portion of the shaping air ring is set at greater than 2 mm.

[Fig. 5] is a view in cross section showing a second shaping air jet portion according to a first variant example.

[Fig. 6] is a view in cross section showing a second shaping air jet portion according to a second variant example.

[Fig. 7] is a structural diagram showing a rotary atomization head-type coating machine according to a second embodiment of the present invention.

[Fig. 8] is a structural diagram showing an electrostatic coating apparatus according to a third embodiment of the present invention.

[Embodiments of the Invention]

[0016] The rotary atomization head-type coating machine and electrostatic coating apparatus according to an embodiment of the present invention will be described in detail below with reference to the appended drawings.

[0017] Fig. 1-4 show a first embodiment of the present invention. Rotary atomization head-type coating machines include electrostatic coating machines which perform coating by applying a high voltage to a paint being sprayed, and non-electrostatic coating machines which perform coating without applying a high voltage to the paint. The embodiment given below will describe the example of a rotary atomization head-type coating machine configured as a direct-charging electrostatic coating machine which applies a high voltage directly to the paint. The same effects can also be achieved in the flow of shaping air when the present invention is applied to a non-electrostatic coating machine.

[0018] In fig. 1, a rotary atomization head-type coating machine 1 according to a first embodiment of the present invention is configured as a direct-charging electrostatic coating machine which applies a high voltage directly to a paint by means of a high-voltage generator (not depicted). The rotary atomization head-type coating machine 1 is mounted at a tip end of an arm of a coating robot (not depicted), for example. The rotary atomization head-type coating machine 1 comprises: a housing 2, an air motor 3, a rotary shaft 4, a feed tube 5, a rotary atomization head 6, a shaping air ring 7, a first shaping air jet portion 8, and a second shaping air jet portion 9, which will be described below.

[0019] The housing 2 is formed as a cylindrical body which is mounted at the tip end of the coating robot arm. A motor accommodating portion (not depicted) for accommodating the air motor 3 opens toward the front on an inner circumferential side of the housing 2. Here, the motor accommodating portion comprises a circular stepped hole and has an axis 0-0 at the centre, extending in a longitudinal direction. The axis 0-0 constitutes a rotational axis (centre axis) of the air motor 3, the rotary shaft 4, and the rotary atomization head 6. The shaping air ring 7 is further provided on the front side of the housing 2.

[0020] The air motor 3 is provided on the axis 0-0 inside the housing 2. The air motor 3 is powered by compressed air and rotates the rotary shaft 4 and the rotary atomization head 6 at a high speed of 3k to 100 krpm. The air motor 3 comprises: a stepped cylindrical motor case 3A mounted in the motor accommodating portion of the housing 2; a turbine rotatably provided at a rear side of the motor case 3A; and air bearings (neither of which is depicted) which are provided in the motor case 3A and rotatably support the rotary shaft 4. The turbine controls the rotation speed in accordance with a flow rate of supplied turbine air, that is, controls the rotation speed of the rotary atomization head 6.

[0021] The rotary shaft 4 is rotatably supported by way of the air bearings in a state of extending in the longitudinal direction coaxially with the axis 0-0 of the air motor 3. The rotary shaft 4 is formed as a hollow cylindrical body having a rear portion which is attached as a single piece to the centre of the turbine, and a front portion 4A which protrudes from the motor case 3A. The rotary atomization head 6 is mounted on the front portion 4A of the rotary shaft 4.

[0022] The feed tube 5 extends through the inside of the rotary shaft 4 as far as the front portion 4A of the rotary shaft 4. A front side of the feed tube 5 protrudes from the front portion 4A of the rotary shaft 4 and extends into the rotary atomization head 6. A rear end side of the feed tube 5 is fixedly attached to a central position of the housing 2.

[0023] The feed tube 5 is formed with double pipes which are coaxially arranged. A flow path in the centre of the double pipes forms a paint flow path 5A, and an outside annular flow path forms a cleaning fluid flow path 5B. Furthermore, the paint flow path 5A and the cleaning fluid flow path 5B are connected to supply sources (not depicted) for a paint and a cleaning fluid (a solvent or air, etc.), respectively. By this means, the feed tube 5 supplies the paint from the paint flow path 5A toward the rotary atomization head 6 when a coating operation is performed. Meanwhile, the feed tube 5 supplies the cleaning fluid from the cleaning fluid flow path 5B toward the rotary atomization head 6 when an operation to clean adhered paint is performed. It should be noted that the feed tube may be constructed with a single flow path which is switched for both paint and cleaning fluid.

[0024] The rotary atomization head 6 atomizes and sprays the paint supplied from the feed tube 5. The rotary atomization head 6 has a rear mounting portion 6A which is mounted on the front portion 4A of the rotary shaft 4. The rotary atomization head 6 is rotated at high speed together with the rotary shaft 4 by means of the air motor 3.

[0025] The rotary atomization head 6 comprises: an outer circumferential surface 6B which opens out in a cup shape from the mounting portion 6A toward the front; and an inner circumferential surface 6C which opens out into a funnel shape toward the front and thereby forms a paint thin film-forming surface which diffuses the paint supplied from the feed tube 5 while forming a thin film thereof. Furthermore, a front end of the inner circumferential surface 6C forms a discharge edge 6D for discharging the paint diffused by the inner circumferential surface 6C when the rotary atomization head 6 rotates.

[0026] Meanwhile, a disc-shaped hub member 6E is provided on an inner side of the rotary atomization head 6 at a position in the interior of the inner circumferential surface 6C (toward the mounting portion 6A). The hub member 6E is capable of smoothly guiding the paint supplied from the feed tube 5 to the inner circumferential surface 6C. A front side portion 6F on the discharge edge 6D side of the outer circumferential surface 6B of the rotary atomization head 6 faces, in a

radial direction, an inner cylinder surface 7A of the shaping air ring 7 which will be described later.

[0027] The shape of the front side portion 6F of the rotary atomization head 6 will be described in detail here. As shown in fig. 2, the front side portion 6F preferably has a shape with a uniform outer diameter dimension in the longitudinal direction (a shape in which the dimension of a gap from the inner cylinder surface 7A of the shaping air ring 7 is constant). In this case, if a point P1 is a boundary position with the discharge edge 6D forming the front end of the front side portion 6F, then the front side portion 6F is preferably formed along a straight line A extending through the point P1 parallel with the axis 0-0. Meanwhile, inclination (a tapered shape) of the front side portion 6F in a direction of decreasing diameter toward the rear is permitted within a predetermined angular range. Specifically, an angle α of an inclined straight line B (the two-dot chain line) passing through the point P1 in relation to the straight line A is set at 10° or less. That is to say, the angle α of the front side portion 6F in a direction of decreasing diameter from the discharge edge 6D toward the rear is set as in the following expression 1.

$$[\text{Expression 1}] \quad 0^\circ \leq \alpha \leq 10^\circ$$

[0028] The rotary atomization head 6 is supplied with the paint from the feed tube 5 while being rotated at high speed by means of the air motor 3. As a result, the rotary atomization head 6 diffuses the paint while forming a thin film thereof at the inner circumferential surface 6C (paint thin film-forming surface), and sprays the paint from the discharge edge 6D as innumerable paint particles atomized by means of centrifugal force.

[0029] The shaping air ring 7 is provided on an outer circumferential side of the rotary atomization head 6. The shaping air ring 7 is formed in a stepped cylindrical shape and is provided on the front side of the housing 2 so as to surround the rotary atomization head 6. The shaping air ring 7 comprises: the inner cylinder surface 7A; a front outer cylinder surface 7B positioned on a front side; a rear outer cylinder surface 7C positioned on a rear side; a step portion 7D between the front outer cylinder surface 7B and the rear outer cylinder surface 7C; and a front end portion 7E positioned at the very front.

[0030] The inner cylinder surface 7A is formed as a cylindrical surface with a uniform inner diameter dimension, which has a larger inner diameter dimension than the outer diameter dimension of the outer circumferential surface 6B of the rotary atomization head 6 and extends in the longitudinal direction with this inner diameter dimension. A front side portion of the inner cylinder surface 7A lies over and around the outer circumferential surface 6B with a gap therebetween. The first shaping air jet portion 8 which will be described later is therefore formed between the outer circumferential surface 6B and the inner circumferential surface 7A.

[0031] A radial dimension of the gap between the front side portion 6F of the outer circumferential surface 6B of the rotary atomization head 6, and the inner cylinder surface 7A of the shaping air ring 7 will be described in detail here with reference to fig. 2. If a point P2 is a corner portion (boundary portion) between the inner cylinder surface 7A and the front end portion 7E, then this gap dimension may be expressed as a radial dimension a between the point P2 and the point P1 on the rotary atomization head 6. This gap dimension a is set as in expression 2 below.

$$[\text{Expression 2}] \quad 0.1 \text{ mm} \leq a \leq 1.0 \text{ mm}$$

[0032] As a result, a jetting port of the first shaping air jet portion 8 can be narrowed to the gap dimension a , and a jetting direction and convergence, etc. of first shaping air jetted from the first shaping air jet portion 8 can be improved. Moreover, the first shaping air jet portion may also be formed as multiple slits or square holes running in the circumferential direction by providing multiple partition plates extending inward from the inner cylinder surface of the shaping air ring at intervals in the circumferential direction. In this case also, the inner cylinder surface of the shaping air ring comprising the slits or square holes which are continuous in the circumferential direction is formed in such a way that the part facing the outer circumferential surface of the rotary atomization head has a uniform inner diameter dimension.

[0033] Furthermore, the front end portion 7E (between the point P2 and a point P3) of the shaping air ring 7 is disposed at a position set back by a dimension b to the rear of the discharge edge 6D (point P1) of the rotary atomization head 6. This dimension b is set as an expression 3 below.

$$[\text{Expression 3}] \quad 0.1 \text{ mm} \leq b \leq 10.0 \text{ mm}$$

[0034] The front end portion 7E of the shaping air ring 7 is thus disposed in a range of 0.1-10.0 mm to the rear of the discharge edge 6D of the rotary atomization head 6, whereby it is possible to create an air flow with little turbulence in the vicinity of the end portion of the rotary atomization head 6. As a result, the flow of paint particles discharged from the rotary atomization head 6 can be stabilized, enabling better coating efficiency. Furthermore, the paint discharged from the discharge edge 6D of the rotary atomization head 6 can be prevented from adhering to the front end portion 7E.

[0035] In addition, if P3 is a corner portion (boundary portion) between the front outer cylinder surface 7B and the front end portion 7E, then a radial width dimension of the front end portion 7E of the shaping air ring 7 constitutes a radial

dimension c between the point P2 and the point P3. This width dimension c is set as in expression 4 below. A lower limit value of the width dimension c is determined by machining accuracy and mechanical rigidity, etc. of the front end portion 7E of the shaping air ring 7.

$$[\text{Expression 4}] \quad c \leq 2 \text{ mm}$$

[0036] Here, when the rotary atomization head 6 rotates, a flow of air (swirling flow) is generated in a direction tangential to the outer circumferential surface of the rotary atomization head 6. The results of thorough investigations carried out by the inventor of this application showed that when a wide end face is present close to the rotary atomization head 6 because of the front end portion 7E, a portion of the swirling flow flows backward along an outer cylinder surface 101A of a shaping air ring 101, as shown in fig. 4. To describe this specifically, if the width dimension of a front end portion 101B of the shaping air ring 101 is set at greater than 2 mm, air in the vicinity of the front end portion 101B is carried away by the swirling flow. This causes a reduction in pressure in the vicinity of the front side of the front end portion 101B, so a portion of the swirling flow flows to the rear side along the outer cylinder surface 101A side of the shaping air ring 101 due to the Coanda effect, as shown by the arrows in fig. 4. Shaping air is not being jetted in the explanatory diagram of fig. 4.

[0037] The flow of air in fig. 4 is opposite to the flow during coating where the paint particles are carried forward. This means that it is necessary to increase the flow rate of shaping air so that the paint particles can be supplied forward against the flow of air in the opposite direction. When the flow rate of shaping air is increased, however, this affects the flow velocity of the air stream flowing close to the object being coated, and leads to a reduction in coating efficiency.

[0038] In contrast to this, when the width dimension c of the front end portion 7E is set at 2 mm or less as in the present embodiment, there is no large air pocket formed in the vicinity of the front side of the front end portion 7E, and a reduction in pressure at the front side of the front end portion 7E can therefore be suppressed. As a result, a flow of air to the rear side along the front outer cylinder surface 7B side of the shaping air ring 7 can be suppressed, and it is possible to produce a flow of air in the radial direction (radiating direction), as shown by the arrows in fig. 3. That is to say, a flow in the opposite direction to the paint particles can be suppressed, and the flow rate of shaping air can therefore be reduced so that air flow in the vicinity of the object being coated can be suppressed, and this enables better coating efficiency of the paint particles. The width dimension c of the front end portion 7E is preferably the smallest possible value in order to suppress an air pocket in the vicinity of the front side of the front end portion 7E. Meanwhile, the width dimension c of the front end portion 7E is preferably a large value within the range of 2 mm or less, to take account of mechanical strength, etc. of the front end portion 7E. Taking account of both of these characteristics, the width dimension c of the front end portion 7E is appropriately set within the range of 2 mm or less.

[0039] The front outer cylinder surface 7B forming the outer cylinder surface of the shaping air ring 7 is formed so as to open out from the front end portion 7E toward the rear (so that a diameter dimension thereof increases). Specifically, the front outer cylinder surface 7B is formed as a tapered surface having a taper angle β in relation to a straight line C extending in the longitudinal direction through the point P3 parallel to the axis 0-0. The taper angle β of the front outer cylinder surface 7B is set as in expression 5 below.

$$[\text{Expression 5}] \quad \beta \leq 25^\circ$$

[0040] When the taper angle β of the front outer cylinder surface 7B is set in this way at 25° or less in relation to the straight line C (axis 0-0), in other words, in a configuration in which the taper angle β of the front outer cylinder surface 7B is reduced so as to approach the axis 0-0, it is possible to reduce the air entrained by the swirling flow generated by rotation of the rotary atomization head 6, and a flow in the opposite direction causing the paint particles to flow to the rear side can be suppressed. The taper angle β should therefore be 25° or less and may be 0° , for example. However, the thickness of the front outer cylinder surface 7B decreases overall as the taper angle β become smaller, and there is a reduction in mechanical strength. Taking account of both of these characteristics, the taper angle β of the front outer cylinder surface 7B is therefore suitably set within a range of 25° or less.

[0041] The first shaping air jet portion 8 is provided on an outer circumferential side of the rotary atomization head 6. The first shaping air jet portion 8 jets first shaping air toward the paint discharged from the discharge edge 6D. The first shaping air jet portion 8 is formed as an annular gap between the outer circumferential surface 6B of the rotary atomization head 6 and the inner cylinder surface 7A of the shaping air ring 7. As a result, there are no obstructions in front of the first shaping air jet portion 8, which can therefore stably jet the first shaping air. The first shaping air jet portion 8 is connected to a first shaping air source (not depicted) via a first shaping air supply path 8A, etc.

[0042] The inner cylinder surface 7A of the shaping air ring 7 is formed with a uniform inner diameter dimension. Meanwhile, the angle α of the front side portion 6F on the outer circumferential surface 6B of the rotary atomization head 6 is formed in a range of $0-10^\circ$. The first shaping air jet portion 8 is formed by a gap which is largely uniform in the longitudinal direction. Furthermore, the gap dimension a of the jetting port of the first shaping air jet portion 8 is narrowed to 0.1-1.0 mm.

By this means, air flows as a laminar flow at the first shaping air jet portion 8, and first shaping air which has been adjusted in terms of jetting direction and convergence, etc. can be sprayed onto the paint particles.

[0043] The second shaping air jet portion 9 is positioned radially outside the first shaping air jet portion 8, and is disposed surrounding the rotary atomization head 6. The second shaping air jet portion 9 jets second shaping air toward the paint discharged from the discharge edge 6D of the rotary atomization head 6. The second shaping air jet portion 9 is formed by multiple holes opening in a circumferential arrangement at the step portion 7D of the shaping air ring 7. The second shaping air jet portion 9 is connected to a second shaping air source (not depicted) via a second shaping air supply path 9A, etc. It should be noted that it is equally possible to adopt a configuration which dispenses with the second shaping air jet portion 9 so that shaping air is jetted only from the first shaping air jet portion 8.

[0044] Here, an imaginary tapered surface D is provided, opening out toward the rear in relation to the straight line C which extends in the longitudinal direction through the point P3 parallel to the axis 0-0. Furthermore, the imaginary tapered surface D is such that a taper angle γ in relation to the straight line C is set at 25° . Additionally, the second shaping air jet portion 9 is disposed on an inner side of the imaginary tapered surface D (at a position close to the axis 0-0). As a result, air around the rotary atomization head 6 is able to flow in the radial direction (radiating direction) against the Coanda effect, which attempts to produce a flow of air toward the rear along the outer cylinder surface 7B, so it is possible to reduce the flow rate of shaping air and to suppress air flow in the vicinity of the object being coated, enabling better coating efficiency of the paint particles.

[0045] The rotary atomization head-type coating machine 1 according to this embodiment has the configuration as described above, and the operation when coating work is performed by using this rotary atomization head-type coating machine 1 will be described next.

[0046] Turbine air is first of all supplied to the turbine of the air motor 3, and the rotary shaft 4 and the rotary atomization head 6 are rotated at high speed by means of the air motor 3. In this state, paint from the paint supply source is supplied to the rotary atomization head 6 through the paint flow path 5A in the feed tube 5. The rotary atomization head 6 sprays the supplied paint as paint particles by this means.

[0047] In this case, the rotary atomization head 6 is connected to the high-voltage generator via the air motor 3 and the rotary shaft 4, etc., and a high voltage is applied to the paint flowing over the surface of the rotary atomization head 6. As a result, the paint particles sprayed from the rotary atomization head 6, which is to say charged paint particles, can fly toward the object being coated such as a motor vehicle body which is connected to earth, and a coating surface of the object being coated can be coated with the paint particles.

[0048] Meanwhile, the spray pattern of the paint particles discharged from the discharge edge 6D of the rotary atomization head 6 can be adjusted to a favourable shape because the first shaping air, which is jetted from the first shaping air jet portion 8, and the second shaping air, which is jetted from the second shaping air jet portion 9, are sprayed from the rear.

[0049] Here, the coating efficiency constitutes the ratio of paint adhering to the coating surface to paint which has been sprayed. The coating efficiency can also be improved to a certain extent by appropriately setting various coating conditions when the rotary atomization head-type coating machine disclosed in Patent Document 1 is used. To give one example, when electrostatic coating is performed using a rotary atomization head-type coating machine according to the prior art, the coating efficiency can be improved to around 70-80%, for example, as shown in conventional example 1 in table 2. Meanwhile, when non-electrostatic coating is performed using a rotary atomization head-type coating machine according to the prior art, the coating efficiency is lower than the coating efficiency for electrostatic coating, being 66%, for example, as shown in conventional example 2 in table 4. However, some of the paint particles sprayed from the rotary atomization head 6 are scattered into the surrounding area without reaching the coating surface of the object being coated. For this reason, it was difficult to make the coating efficiency any better in the rotary atomization head-type coating machines of conventional examples 1 and 2.

[0050] The inventor of this application therefore investigated changes in the coating efficiency looking at the structural aspects of the rotary atomization head-type coating machine. The structural aspects of the rotary atomization head-type coating machine include, for example: the width dimension c of the front end portion 7E of the shaping air ring (SA ring) 7; the external taper angle β of the shaping air ring 7, and the gap dimension a of the first shaping air jet portion (first SA jet portion) 8. The inventor of this application then measured the respective coating efficiencies of multiple rotary atomization head-type coating machines having different conditions for the structural aspects. The measurement results are shown in tables 1 and 2 below.

[Table 1]

	SA ring front end portion width dimension (c) [mm]	SA ring external taper angle (β) [°]	First SA jet portion gap dimension (a) [mm]	Rotary atomization head circumference-taper surface angle (α) [°]	SA ring set-back dimension (b) [mm]	Rotary atomization head rotation speed [krpm]	SA flow rate [Nl/min]	Coating distance [mm]	Applied voltage [kV]	Amount of paint particles not directed to object being coated	Amount of paint particles flowing along coating surface of object being coated and not adhering	Coating efficiency [%]
Comparative Example	1	22 (25 or less)	0.1~ 1.0	0	4	20	100~ 300	100 (90~ 110)	-60 (-50 or more)	None	None	98 or more
	1	22	0.1~ 1.0	0	4	20	100~ 300	100	-60	Few	None	95
	2	22	0.1~ 1.0	0	4	20	100~ 300	100	-60	Many	None	90
	3	35	0.1~ 1.0	0	4	20	100~ 300	100	-60	Few	None	95
	4	45	0.1~ 1.0	0	4	20	100~ 300	100	-60	Few	None	93
	5	55	0.1~ 1.0	0	4	20	100~ 300	100	-60	Many	None	90
	6	22	1.1	0	4	20	100~ 300	100	-60	Few	None	95
	7	22	1.2	0	4	20	100~ 300	100	-60	Many	None	92
Example	8	22	1.5	0	4	20	100~ 300	100	-60	Very many	None	88

[Table 2]

	SA ring front end portion width dimension (c) [mm]	SA ring external taper angle (β) [°]	First SA jet portion gap dimension (α) [mm]	Rotary atomization head circumferential surface angle (α) [°]	SA ring set-back dimension (b) [mm]	Rotary atomization head rotation speed [krpm]	SA flow rate [NL/min]	Coating distance [mm]	Applied voltage [kV]	Amount of paint particles not directed to object being coated	Amount of paint particles flowing along surface of object being coated and not adhering	Coating efficiency [%]
Comparative Example	9	22	1.2	10	4	20	100~300	100	-60	Many	None	92
	10	22	1.6	15	4	20	100~300	100	-60	Very many	None	88
	11	22	0.1~1.0	0	15	20	100~300	100	-60	Few	None	96
	12	22	0.1~1.0	0	20	20	100~300	100	-60	Many	None	93
Example	1	30~60	None	45	11	20~40	300~400	200	-80	Very many	Very many	70~80

[Table 3]

	SA ring front end portion width dimension (c) [mm]	SA ring external taper angle (β) [°]	First SA jet portion gap dimension (a) [mm]	Rotary atomization head outer circumferential surface angle		SA ring set-back dimension (b) [mm]	Rotary atomization head rotation speed [krpm]	SA flow rate [Nl/min]	Coating distance [mm]	Applied voltage [kV]	Amount of paint particles not directed to object being coated	Amount of paint particles flowing along surface of object being coated and not adhering	Coating efficiency [%]
				(α)	(θ)								
2	2	22	0.1~1.0	0	0	4	25	100~300	100	-60	Few	None	96
3	2	22	0.1~1.0	0	0	4	35	100~300	100	-60	Many	None	95
4	2	22	0.1~1.0	0	0	4	45	100~300	100	-60	Many	None	93
5	2	22	0.1~1.0	0	0	4	20	400	100	-60	None	Few	96
6	2	22	0.1~1.0	0	0	4	20	500	100	-60	None	Many	95
7	2	22	0.1~1.0	0	0	4	20	600	100	-60	None	Many	92
8	2	22	0.1~1.0	0	0	4	20	100~300	130	-60	None	Few	96
9	2	22	0.1~1.0	0	0	4	20	100~300	150	-60	None	Few	94
10	2	22	0.1~1.0	0	0	4	20	100~300	200	-60	None	Many	90
11	2	22	0.1~1.0	0	0	4	20	100~300	100	-40	None	None	97
12	2	22	0.1~1.0	0	0	4	20	100~300	100	-30	Few	None	92
13	2	22	0.1~1.0	0	0	4	20	100~300	100	0	Few	Many	85

Example

[Table 4]

SA ring front end portion width dimension (c) [mm]	SA ring external taper angle (B) [°]	First SA jet portion gap dimension (a) [mm]	Rotary atomization head outer circumference surface angle (α) [°]	SA ring set-back dimension (b) [mm]	Rotary atomization head rotation speed [krpm]	First SA flow rate [NI/min]	Second SA flow rate [NI/min]	Coating distance [mm]	Applied voltage [kV]	Coating efficiency [%]
14	22	0.1~1.0	0	4	20	100	500	100	0	83
15	22	0.1~1.0	0	4	20	100	500	60	0	86
2	30~60	None	45	11	20	300	100	100	0	66
Conventional Example										
Example										

[0051] The conditions for the structural aspects of the rotary atomization head-type coating machine 1 required in order to improve coating efficiency, which is the main problem addressed by the present invention, will be described with reference to tables 1 and 2.

[0052] Paint particles which are not directed in the direction of the object being coated are present around the tip end of the rotary atomization head 6 because of turbulence being produced in the paint particles. Furthermore, paint particles flowing along the coating surface of the object being coated and not adhering are present at the coating surface. The coating efficiency can be improved by minimizing the paint particles that do not contribute to coating.

[0053] The coating conditions for an existing rotary atomization head-type coating machine which is given as conventional example 1, and the results obtained with those coating conditions will be described. In conventional example 1 given

in table 2, the width dimension c of the front end portion of the shaping air ring (SA ring) is set at 6-8 mm, the external taper angle β of the shaping air ring is set at 30-60°, and there is no first shaping air jet portion (first SA jet portion) present. Furthermore, the outer circumferential surface angle α in the direction of decreasing diameter from the discharge edge of the rotary atomization head toward the rear is set at 45°, the dimension b by which the front end portion of the shaping air ring is set back from the discharge edge of the rotary atomization head is set at 11 mm, the rotation speed of the rotary atomization head is set at 20-40 krpm, the flow rate of shaping air (SA) is set at 300-400 NI/min, the coating distance is set at 200 mm, and the applied voltage is set at 80 kV. As a result, the amount of paint particles not directed to the object being coated is "very many", and the amount of paint particles flowing along the coating surface of the object being coated and not adhering is "very many". These results keep the coating efficiency at 70-80%.

[0054] It should be noted that the amount of paint particles not directed to the object being coated and the amount of paint particles flowing along the coating surface of the object being coated and not adhering are judged at four levels: "none" (so few as to be unmeasurable), "few", "many", and "very many".

[0055] In contrast to this, for the coating conditions with the rotary atomization head-type coating machine 1 according to example 1 of the present invention, as shown in table 1, the width dimension c of the front end portion 7E of the shaping air ring (SA ring) 7 is set at 2 mm, the external taper angle β of the shaping air ring 7 is set at 22°, the gap dimension a of the first shaping air jet portion (first SA jet portion) 8 is set at 0.1-1.0 mm, the angle α of the front side portion 6F (outer circumferential surface) in the direction of decreasing diameter from the discharge edge 6D of the rotary atomization head 6 toward the rear is set at 0°, and the dimension b by which the front end portion 7E of the shaping air ring (SA ring) is set back from the discharge edge 6D of the rotary atomization head 6 is set at 4 mm. Furthermore, the rotation speed of the rotary atomization head 6 is set at 20 krpm, the flow rate of the shaping air (SA) is set at 100-300 NI/min, the coating distance is set at 100 mm, and the applied voltage is set at -60 kV. Here, the amount of paint particles not directed to the object being coated is "none", and the amount of paint particles flowing along the coating surface of the object being coated and not adhering is "none". These results show that example 1 makes it possible to improve the coating efficiency by at least 10% as compared to conventional example 1, and a coating efficiency of 98% or more may be achieved, for example.

[0056] Table 1 gives only the coating efficiency when the coating conditions of example 1 are set. The present invention is not limited to those coating conditions, and the coating efficiency can also be improved in the same way as in example 1, enabling a coating efficiency of 98% or more to be achieved, when the rotary atomization head-type coating machine 1 has coating conditions in which: the width dimension c of the front end portion 7E of the shaping air ring 7 is set at 2 mm or less, the angle α of the front side portion 6F (outer circumferential surface) of the rotary atomization head 6 is set at 0-10°, the set-back dimension b of the shaping air ring 7 is set at 0.1-10.0 mm, the external taper angle β of the shaping air ring 7 is set at 25° or less, the coating distance is set at 90-110 mm, and the applied voltage is set at -50 kV or more

[0057] The reason for this is that the first shaping air is discharged from the first shaping air jet portion 8, which is the gap between the rotary atomization head 6 and the inner cylinder surface 7A of the shaping air ring 7, so that the structure has no obstructions in front of the first shaping air jet portion 8, and the front side portion 6F of the rotary atomization head 6 is parallel to (has a uniform gap width) the inner cylinder surface 7A of the shaping air ring 7. By this means, it is possible to suppress turbulence in the air flow around the rotary atomization head 6 and to stabilize the flow of shaping air without increasing the flow rate of the first shaping air. That is to say, it is possible to suppress non-adhesion of paint particles which arises due to a stream of air flowing over the surface of the object being coated when the flow rate of the shaping air is increased.

[0058] In addition to this, it is also possible to suppress the phenomenon of paint particles flowing toward the rear due to the Coanda effect, by setting the width dimension c of the front end portion 7E of the shaping air ring 7 at 2 mm, and by setting the external taper angle β of the shaping air ring 7 at 22°. Furthermore, it is also possible to both stabilize the first shaping air and increase the flow velocity thereof in order to direct the paint particles towards the object being coated, by setting the gap dimension a of the first shaping air jet portion 8 at 0.1-1.0 mm, by setting the angle α of the front side portion 6F of the rotary atomization head 6 at 0°, and by setting the set back dimension b of the shaping air ring 7 at 4 mm.

[0059] The inventor of this application then investigated the respective coating efficiencies when the value of the width dimension c of the front end portion 7E of the shaping air ring 7 was changed, when the value of the angle α of the front side portion 6F (outer circumferential surface) of the rotary atomization head 6 was changed, when the value of the set-back dimension b of the shaping air ring 7 was changed, and when the value of the external taper angle β of the shaping air ring 7 was changed. The results are shown in comparative examples 1-12 in tables 1 and 2. First of all, in comparative examples 1 and 2, the width dimension c of the front end portion 7E of the shaping air ring (SA ring) 7 is changed, among the coating conditions in example 1. In the case of comparative example 1, in which the width dimension c was changed to 4 mm, the amount of paint particles not directed to the object being coated is "few", and the amount of paint particles flowing along the coating surface of the object being coated and not adhering is "none". The result is a coating efficiency of 95%, for example, which is below that of example 1. Furthermore, in the case of comparative example 2, in which the width dimension c was changed to 6 mm, the amount of paint particles not directed to the object being coated is "many", and the amount of paint particles flowing along the coating surface of the object being coated and not adhering is "none". The result is a coating efficiency of 90%, for example, which is below that of example 1.

[0060] In comparative examples 3-5, the external taper angle β of the shaping air ring 7 is changed, among the coating conditions in example 1. In the case of comparative example 3, in which the external taper angle β was changed to 35° , the amount of paint particles not directed to the object being coated is "few", and the amount of paint particles flowing along the coating surface of the object being coated and not adhering is "none". The result is a coating efficiency of 95%, for example, which is below that of example 1. Furthermore, in the case of comparative example 4, in which the external taper angle β was changed to 45° , the amount of paint particles not directed to the object being coated is "few", and the amount of paint particles flowing along the coating surface of the object being coated and not adhering is "none". The result is a coating efficiency of 93%, for example, which is below that of example 1. In addition, in the case of comparative example 5, in which the external taper angle β was changed to 55° , the amount of paint particles not directed to the object being coated is "many", and the amount of paint particles flowing along the coating surface of the object being coated and not adhering is "none". The result is a coating efficiency of 90%, for example, which is below that of example 1.

[0061] In comparative examples 6-8, the gap dimension a of the first shaping air jet portion (first SA jet portion) 8 is changed, among the coating conditions in example 1. In the case of comparative example 6, in which the gap dimension a was changed to 1.1 mm, the amount of paint particles not directed to the object being coated is "few", and the amount of paint particles flowing along the coating surface of the object being coated and not adhering is "none". The result is a coating efficiency of 95%, for example, which is below that of example 1. Furthermore, in the case of comparative example 7, in which the gap dimension a was changed to 1.2 mm, the amount of paint particles not directed to the object being coated is "many", and the amount of paint particles flowing along the coating surface of the object being coated and not adhering is "none". The result is a coating efficiency of 92%, for example, which is below that of example 1. In addition, in the case of comparative example 8, in which the gap dimension a was changed to 1.5 mm, the amount of paint particles not directed to the object being coated is "very many", and the amount of paint particles flowing along the coating surface of the object being coated and not adhering is "none". The result is a coating efficiency of 88%, for example, which is below that of example 1.

[0062] In comparative examples 9 and 10, the angle α of the front side portion 6F (outer circumferential surface) of the rotary atomization head 6 is changed, among the coating conditions in example 1. In the case of comparative example 9, in which the angle α was changed to 10° , this value of 10° is within the range of the angle α which enables high coating efficiency to be achieved, but the gap dimension a becomes 1.2 mm as a result of changing the angle α to 10° . Consequently, in the case of comparative example 9, the amount of paint particles not directed to the object being coated is "many", and the amount of paint particles flowing along the coating surface of the object being coated and not adhering is "none". The result is a coating efficiency of 92%, for example, which is below that of example 1. Furthermore, in the case of comparative example 10, in which the angle α was changed to 15° , the amount of paint particles not directed to the object being coated is "very many", and the amount of paint particles flowing along the coating surface of the object being coated and not adhering is "none". The result is a coating efficiency of 88%, for example, which is below that of example 1.

[0063] In comparative examples 11 and 12, the set-back dimension b of the shaping air ring (SA ring) 7 is changed, among the coating conditions in example 1. In the case of comparative example 11, in which the set-back dimension b was changed to 15 mm, the amount of paint particles not directed to the object being coated is "few", and the amount of paint particles flowing along the coating surface of the object being coated and not adhering is "none". The result is a coating efficiency of 96%, for example, which is below that of example 1. Furthermore, in the case of comparative example 12, in which the set-back dimension b was changed to 20 mm, the amount of paint particles not directed to the object being coated is "many", and the amount of paint particles flowing along the coating surface of the object being coated and not adhering is "none". The result is a coating efficiency of 93%, for example, which is below that of example 1.

[0064] Looking at the results of comparative examples 1-12 in which structural aspects of the coating conditions were changed, it can be seen that the coating efficiency value can be improved to a certain extent (for example to around 95%). However, the coating efficiencies in all of comparative examples 1-12 are below the coating efficiency of example 1. It can therefore be understood that simultaneously satisfying a large number of the coating conditions, which is shown in example 1, can achieve better coating efficiency than when some of the coating conditions are not satisfied.

[0065] The coating efficiency was then investigated when the rotary atomization head type coating machine 1 of the present invention was used while changing control aspects of the coating conditions. The results are shown in examples 2-13 in table 3. Here, the control aspects of the rotary atomization head-type coating machine 1 include, for example: the rotation speed of the rotary atomization head 6, the flow rate of the shaping air (SA), the coating distance from the rotary atomization head 6 to the coating surface of the object being coated, and the applied voltage. First of all, in examples 2-4, the rotation speed of the rotary atomization head 6 is changed, among the coating conditions in example 1. In the case of example 2, in which the rotation speed was changed to 25 krpm, the amount of paint particles not directed to the object being coated is "few", and the amount of paint particles flowing along the coating surface of the object being coated and not adhering is "none". The result is a coating efficiency of 96%. Furthermore, in the case of example 3, in which the rotation speed was changed to 35 krpm, the amount of paint particles not directed to the object being coated is "many", and the amount of paint particles flowing along the coating surface of the object being coated and not adhering is "none". The result

is a coating efficiency of 95%. In addition, in the case of example 4, in which the rotation speed was changed to 45 krpm, the amount of paint particles not directed to the object being coated is "many", and the amount of paint particles flowing along the coating surface of the object being coated and not adhering is "none". The result is a coating efficiency of 93%.

[0066] In examples 5-7, the flow rate of shaping air (SA) is changed, among the coating conditions in example 1. In the case of example 5, in which the flow rate of first shaping air was changed to 400 NI/min, the amount of paint particles not directed to the object being coated is "none", and the amount of paint particles flowing along the coating surface of the object being coated and not adhering is "few". The result is a coating efficiency of 96%. Furthermore, in the case of example 6, in which the flow rate of first shaping air was changed to 500 NI/min, the amount of paint particles not directed to the object being coated is "none", and the amount of paint particles flowing along the coating surface of the object being coated and not adhering is "many". The result is a coating efficiency of 95%. In addition, in the case of example 7, in which the flow rate of first shaping air was changed to 600 NI/min, the amount of paint particles not directed to the object being coated is "none", and the amount of paint particles flowing along the coating surface of the object being coated and not adhering is "many". The result is a coating efficiency of 92%.

[0067] In examples 8-10, the coating distance is changed, among the coating conditions in example 1. In the case of example 8, in which the coating distance was changed to 130 mm, the amount of paint particles not directed to the object being coated is "none", and the amount of paint particles flowing along the coating surface of the object being coated and not adhering is "few". The result is a coating efficiency of 96%. In the case of example 9, in which the coating distance was changed to 150 mm, the amount of paint particles not directed to the object being coated is "none", and the amount of paint particles flowing along the coating surface of the object being coated and not adhering is "few". The result is a coating efficiency of 94%. In the case of example 10, in which the coating distance was changed to 200 mm, the amount of paint particles not directed to the object being coated is "none", and the amount of paint particles flowing along the coating surface of the object being coated and not adhering is "many". The result is a coating efficiency of 90%.

[0068] In examples 11-13, the applied voltage is changed, among the coating conditions in example 1. In the case of example 11, in which the applied voltage was changed to -40 kV, the amount of paint particles not directed to the object being coated is "none", and the amount of paint particles flowing along the coating surface of the object being coated and not adhering is "none". The result is a coating efficiency of 97%. Furthermore, in the case of example 12, in which the applied voltage was changed to -30 kV, the amount of paint particles not directed to the object being coated is "few", and the amount of paint particles flowing along the coating surface of the object being coated and not adhering is "none". The result is a coating efficiency of 92%. In addition, in the case of example 13, in which the applied voltage was changed to 0 kV (non-electrostatic), the amount of paint particles not directed to the object being coated is "few", and the amount of paint particles flowing along the coating surface of the object being coated and not adhering is "many". The result is a coating efficiency of 85%.

[0069] Looking at the results of examples 2-13 in which control aspects of the coating conditions were changed, it can be seen that a coating efficiency of 90% or more can be ensured in examples 2-12 in which electrostatic coating is performed. It can therefore be understood that examples 2-12, in which electrostatic coating is performed, make it possible to improve the coating efficiency by at least 10% as compared to conventional example 1, in which electrostatic coating is performed. Furthermore, example 13, in which non-electrostatic coating is performed, also makes it possible to improve the coating efficiency as compared to when non-electrostatic coating is performed with the coating machine of conventional example 2. Consequently, even if control aspects of the production conditions differ from those of example 1, depending on the viscosity of the paint used and the shape of the object being coated, etc., for example, use of the rotary atomization head-type coating machine 1 of examples 1-13 achieves better coating efficiency than use of the coating machines of conventional examples 1 and 2. That is to say, it can be understood that by setting structural aspects of the coating conditions at predetermined values, as with the rotary atomization head-type coating machine 1 of example 1, better coating efficiency can be achieved than when coating machines having other structures are used.

[0070] The coating efficiency was then investigated when the rotary atomization head-type coating machine 1 of the present invention was used to perform non-electrostatic coating. The results are shown in examples 14 and 15 in table 4. Here, the structural aspects of the coating conditions in the rotary atomization head-type coating machine 1 according to examples 14 and 15 of the present invention were the same as the conditions in example 1. Furthermore, the structural aspects of the coating conditions in the rotary atomization head-type coating machine according to conventional example 2 were the same as the conditions in conventional example 1. For the other coating conditions in examples 14 and 15, the rotation speed of the rotary atomization head 6 is 20 krpm, the flow rate of the first shaping air (SA) is 100 NI/min, and the flow rate of the second shaping air (SA) is 500 NI/min. Furthermore, in conventional example 2, the flow rate of the first shaping air (SA) is 300 NI/min, and the flow rate of the second shaping air (SA) is 100 NI/min. The other coating conditions are the same as in example 14. Moreover, in examples 14 and 15 and conventional example 2, an amount of paint ejected is 300 cc/min, and a movement speed (robot speed) of the coating machine is 500 mm/sec. In examples 14 and 15 and conventional example 2, the applied voltage is set at 0 kV and the results given are for a case in which non-electrostatic coating is performed.

[0071] In example 14 and conventional example 2, the coating distance is set at 100 mm. In conventional example 2, the

coating efficiency is 66%, for example. In contrast to this, example 14 makes it possible to improve the coating efficiency by at least 10% as compared to conventional example 2, and a coating efficiency of 83% may be achieved, for example. Furthermore, in example 15, a shorter coating distance is set than in example 14, the coating distance being set at 60 mm. The coating efficiency of example 15 is higher than that of example 14, with the coating efficiency being 86%, for example. As shown by these results, it can be understood that by setting structural aspects of the coating conditions at predetermined values, as with the rotary atomization head-type coating machines 1 of examples 14 and 15, better coating efficiency can be achieved than when the coating machine of conventional example 2 having another structure is used.

[0072] According to this embodiment, the inner cylinder surface 7A of the shaping air ring 7 is such that at least the front side portion facing the outer circumferential surface 6B of the rotary atomization head 6 is formed with a uniform inner diameter dimension. Furthermore, the first shaping air jet portion a is formed as an annular gap between the outer circumferential surface 6B (front side portion 6F) of the rotary atomization head 6 and the inner cylinder surface 7A of the shaping air ring 7. In addition, the radial dimension a of the gap between the front side portion 6F of the rotary atomization head 6 and the inner cylinder surface 7A of the shaping air ring 7 is set at 0.1-1.0 mm. The front end portion 7E of the shaping air ring 7 is disposed at a position 0.1-10.0 mm to the rear of the discharge edge 6D of the rotary atomization head 6. The radial width dimension c of the front end portion 7E of the shaping air ring 7 is set at 2 mm or less. The front outer cylinder surface 7B of the shaping air ring 7 is such that the taper angle β opening out toward the rear from the front end portion 7E of the shaping air ring 7 is set at 25° or less in relation to the axis 0-0. The second shaping air jet portion 9 is disposed inside the imaginary tapered surface D having a taper angle opening out from the front end portion 7E of the shaping air ring 7 toward the rear of 25°.

[0073] Accordingly, the inner cylinder surface 7A of the shaping air ring 7 is formed with a uniform inner diameter dimension, and the angle α of the front side portion 6F of the outer circumferential surface 6B of the rotary atomization head 6 is formed in a range of 0-10°, so the first shaping air jet portion 8 is formed by a uniform gap in the longitudinal direction. Furthermore, the gap dimension a of the jetting port of the first shaping air jet portion 8 is narrowed to 0.1-1.0 mm, so the first shaping air which has been adjusted in terms of jetting direction and convergence, etc. can be sprayed onto the paint particles

[0074] Furthermore, the front end portion 7E of the shaping air ring 7 is disposed in a range of 0.1-10.0 mm to the rear of the discharge edge 6D of the rotary atomization head 6, so it is possible to stabilize the flow of paint particles discharged from the rotary atomization head 6 and to achieve better coating efficiency. It is also possible to prevent the paint discharged from the discharge edge 6D of the rotary atomization head 6 from adhering to the front end portion 7E.

[0075] Furthermore, the width dimension c of the front end portion 7E of the shaping ring 7 is set at 2 mm or less, so it is possible to prevent the formation of a large air pocket in the vicinity of the front side of the front end portion 7E. That is to say, by suppressing a reduction in pressure on the front side of the front end portion 7E, it is possible to prevent a flow of the paint particles in the opposite direction toward a low-pressure region. As a result, the flow of air in the vicinity of the object being painted can be stabilized by reducing the flow rate of first shaping air and second shaping air, and this enables better coating efficiency of the paint particles.

[0076] Furthermore, the taper angle β of the front outer cylinder surface 7B of the shaping air ring 7 is set at 25° or less in relation to the straight line C parallel to the axis 0-0, which is a configuration approaching the axis 0-0. As a result, it is possible to reduce the air entrained by the swirling flow generated by rotation of the rotary atomization head 6, and a flow in the opposite direction causing the paint particles to flow to the rear side can be suppressed. Moreover, the paint particles moving through the air are not entrained in a flow in the opposite direction (turbulent flow), so it is possible to prevent the paint from adhering to the rotary atomization head 6 or the shaping air ring 7.

[0077] In addition, the second shaping air jet portion 9 is disposed inside the imaginary tapered surface 1) whereof the taper angle γ in relation to the straight line C is set at 25° (disposed at a position close to the axis 0-0). As a result, air around the rotary atomization head 6 is able to flow in the radial direction (radiating direction) against the Coanda effect, which attempts to produce a flow of air toward the rear along the outer cylinder surface 7B, so it is possible to reduce the flow rate of shaping air and to suppress air flow in the vicinity of the object being coated, enabling better coating efficiency of the paint particles.

[0078] The coating efficiency of the rotary atomization head-type coating machine 1 can be improved as a result. Furthermore, there is no need to change the coating conditions such as rotation speed of the rotary atomization head 6 or the flow rate of shaping air or paint, so it is possible to achieve better coating efficiency while maintaining productivity by maintaining a range for coating by one rotary atomization head-type coating machine 1.

[0079] It should be noted that the first embodiment described an exemplary case in which the shaping air ring 7 comprises the step portion 7D between the front outer cylinder surface 7B and the rear outer cylinder surface 7C, and the second shaping air jet portion 9 is formed as multiple holes opening in a circumferential arrangement at the step portion 7D. The present invention is not limited to this embodiment, however, and the present invention may equally be configured as in a first variant example shown in fig. 5. That is to say, a second shaping air jet portion 11 according to the first variant example is disposed in a circumferential arrangement in the shaping air ring 7, and a tip end thereof opens at the inner

cylinder surface 7A around the front side portion 6F of the rotary atomization head 6. By this means, the second shaping air jetted from the second shaping air jet portion 11 can be merged with the first shaping air jetted from the first shaping air jet portion 8, which makes it possible to increase the flow velocity of the shaping air. As a result, even highly viscous paint can be atomized by the high-velocity shaping air and the coating finish quality can be improved. The first variant example may likewise also be applied to the second and third embodiments which will be described below.

[0080] Furthermore, the present invention may also be configured as in a second variant example shown in fig. 6. That is to say, a second shaping air jet portion 21 according to the second variant example is formed as a slit opening at the inner cylinder surface 7A of the shaping air ring 7 to the rear of the first shaping air jet portion 8. By this means, the second shaping air jet portion 21 can cause the second shaping air to merge with the first shaping air jetted from the first shaping air jet portion 8, in the same way as the second shaping air jet portion 11 according to the first variant example, which makes it possible to increase the flow velocity of the shaping air. As a result, the second shaping air jet portion 21 can be provided without increasing the radial thickness of the front end portion 7E of the shaping air ring 7, so a balance between better coating efficiency and better coating finish quality can be achieved. Furthermore, when the second shaping air jet portion 21 extends as far as the vicinity of the jetting port of the first shaping air jet portion 8, the angle α of the front side portion 6F of the outer circumferential surface 6B of the rotary atomization head 6 may be a value greater than 10° , as shown in examples 16 and 17 in table 5. That is to say, the angle α may be greater than 10° provided that the air flows out from the first shaping air jet portion 8 as a laminar flow. The second variant example may likewise also be applied to the second and third embodiments which will be described below.

[Table 5]

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SA ring front end portion width dimension (c) [mm]	SA ring external taper angle (φ) [°]	First SA jet portion gap dimension (a) [mm]	Rotary atomization front surface angle (θ) [°]	SA ring back-portion dimension (b) [mm]	Rotary atomization head rotation speed [krpm]	SA flow rate [Nl/min]	Coating distance [mm]	Applied voltage [kV]	Amount of paint particles not directed to object being coated	Amount of paint particles flowing along coating surface of object being coated and not adhering	Coating efficiency [%]
2	22	0.1~1.0	15	4	20	100~300	100	-60	Few	None	94
2	22	0.1~1.0	80	4	20	100~300	100	-60	Many	None	90
Example 1											
Example 2											

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[0081] In addition, the first embodiment described an example of the rotary atomization head-type coating machine 1 as a direct-charging electrostatic coating machine which applies a high voltage directly to the paint supplied to the rotary atomization head 6. The present invention is not limited to this embodiment, however, and the present invention may equally be configured for application to a rotary atomization head-type coating machine of the indirect-charging type, which comprises an external electrode for discharging a high voltage at an outer circumferential position of the housing, and applies the high voltage by means of discharge from the external electrode to the paint particles sprayed from the rotary atomization head. In addition, the present invention may also be applied to a non-electrostatic coating machine

which performs coating without applying a high voltage to the paint.

[0082] Next, fig. 7 shows a second embodiment of the present invention. The feature of the second embodiment lies in the fact that a shaping air control device is provided for controlling a jetting amount of the first shaping air and a jetting amount of the second shaping air, and the shaping air control device controls a ratio of the jetting amount of the first shaping air and the jetting amount of the second shaping air so that a spray pattern of the paint discharged from the rotary atomization head decreases in diameter. It should be noted that components of the second embodiment which are the same as in the first embodiment above are assigned the same reference numbers and will not be described again.

[0083] In fig. 7, a rotary atomization head-type coating machine 31 according to the second embodiment comprises: a housing 2, an air motor 3, a rotary shaft 4, a feed tube 5, a rotary atomization head 6, a shaping air ring 7, a first shaping air jet portion 8, and a second shaping air jet portion 9, in the same way as the rotary atomization head-type coating machine 1 according to the first embodiment. The rotary atomization head-type coating machine 31 according to the second embodiment further comprises a shaping air control device 34 which will be described below.

[0084] The first shaping air jet portion 8 is connected to a first shaping air source (first SA source) 32 via a first shaping air supply path 8A, etc. Furthermore, the second shaping air jet portion 9 is connected to a second shaping air source (second SA source) 33 via a second shaping air supply path 9A, etc. The jetting amounts of shaping air from the first shaping air source 32 and the second shaping air source 33 are then controlled by means of the shaping air control device 34.

[0085] The shaping air control device 34 controls: a flow rate (jetting amount) of the first shaping air discharged from the first shaping air jet portion 8, and a flow rate (jetting amount) of the second shaping air jetted from the second shaping air jet portion 9. Specifically, the shaping air control device 34 controls the ratio of the jetting amount of the first shaping air and the jetting amount of the second shaping air so that the spray pattern of the paint discharged from the rotary atomization head 6 decreases in diameter.

[0086] An example of the ratio when the shaping air control device 34 controls the jetting amount of the first shaping air and the jetting amount of the second shaping air will be described here. For example, when coating is performed with a large spray pattern (large pattern), the shaping air control device 34 sets the first shaping air jetting amount at 100 NI/min and the second shaping air jetting amount at 50 NI/min under conditions of a diameter dimension of the rotary atomization head 6 of 70 mm, a rotation speed of 20 krpm, and a paint spraying amount of 250 cc/min. That is to say, for the large pattern, the ratio of the first shaping air jetting amount and the second shaping air jetting amount is set at 6:1, whereby the spray pattern of the paint discharged from the rotary atomization head 6 can be reduced in diameter.

[0087] Furthermore, when coating is performed with a spray pattern which is smaller than the large pattern (small pattern), the shaping air control device 34 sets the first shaping air jetting amount at 50 NI/min and the second shaping air jetting amount at 400 NI/min under conditions of a diameter dimension of the rotary atomization head 6 of 70 mm, a rotation speed of 20 krpm, and a paint spraying amount of 150 cc/min. That is to say, for the small pattern, the ratio of the first shaping air jetting amount and the second shaping air jetting amount is set at 1:8, whereby the spray pattern of the paint discharged from the rotary atomization head 6 can be reduced in diameter.

[0088] The rotary atomization head-type coating machine 31 according to the second embodiment configured in the manner above can thus also achieve the same action and effect as those of the first embodiment. In particular, the rotary atomization head type coating machine 31 according to the second embodiment is capable of controlling, by means of the shaping air control device 34, the ratio of the jetting amount of first shaping air from the first shaping air jet portion 8 and the jetting amount of second shaping air from the second shaping air jet portion 9. This makes it possible to reduce the diameter of the spray pattern of paint discharged from the rotary atomization head 6. Scattering of the sprayed paint into the surrounding area can therefore be suppressed, enabling better coating efficiency.

[0089] Next, fig. 8 shows a third embodiment of the present invention. The feature of the third embodiment lies in the fact that a high-voltage generator is provided for applying a high voltage to the paint discharged from the rotary atomization head, a coating machine movement means on which the rotary atomization head-type coating machine is mounted is provided, and a movement means control device is provided for controlling the coating machine movement means, the movement means control device controlling the coating machine movement means so that the coating distance from the discharge edge to the coating surface of a coating target is kept at 90-150 mm. It should be noted that components of the third embodiment which are the same as in the first embodiment above are assigned the same reference numbers and will not be described again.

[0090] In fig. 8, an electrostatic coating apparatus 41 according to the third embodiment comprises: the rotary atomization head-type coating machine 1 according to the first embodiment; a coating robot 43 which will be described below; and a robot control device 44. The rotary atomization head-type coating machine 1 comprises: a housing 2, an air motor 3, a rotary shaft 4, a feed tube 5, a rotary atomization head 6, a shaping air ring 7, a first shaping air jet portion 8, a second shaping air jet portion 9, and a high-voltage generator 42 which will be described below.

[0091] The high-voltage generator 42 (denoted by the dotted lines) is provided in the housing 2. The high-voltage generator 42 is formed by a Cockcroft circuit, for example, and boosts the voltage supplied from a power source device (not depicted) to between -60 and -120 kV. An output side of the high-voltage generator 42 is then electrically connected to the air motor 3, and by this means the high-voltage generator 42 applies a high voltage to the rotary atomization head 6 via the

rotary shaft 4, and applies the high voltage to the paint discharged from the rotary atomization head 6.

[0092] The coating robot 43 serving as the coating machine movement means comprises a movable arm 43B on a support stand 43A. The rotary atomization head-type coating machine 1 is mounted at a tip end of the arm 43B. The coating robot 43 moves the arm 43B, etc. in accordance with a control signal from the robot control device 44 which will be described below. A movement means which performs only reciprocating movement, etc., for example, may also be used as the coating machine movement means, in addition to a multi-jointed robot.

[0093] The robot control device 44 serving as the movement means control device controls the coating robot. The robot control device 44 controls a coating distance L, etc. from the discharge edge 6D of the rotary atomization head 6 constituting the rotary atomization head-type coating machine 1 to a coating surface 45A of an object 45 being coated which constitutes the coating target. Specifically, the robot control device 44 controls the coating robot 43 so that the coating distance L, is kept at 90-150 mm, in a state in which a high voltage has been applied by means of the high-voltage generator 42 to the paint discharged from the rotary atomization head 6. When coating is performed with the coating distance L kept at 90-150 mm in this way, the coating efficiency can be improved to around 95%, for example.

[0094] If the coating distance L is greater than the upper limit value of 150 mm here, this weakens the line of electric force formed with the object 45 being coated, and the coating efficiency decreases (the coating efficiency is around 80%, for example). If the coating distance L is smaller than the lower limit value of 90 mm, on the other hand, there is no reduction in coating efficiency but there is a risk of frequent high voltage abnormalities because of the proximity to the object 45 being coated, which might lead to stoppage of the line. The lower limit value of the coating distance L is therefore set at 90 mm.

[0095] The electrostatic coating apparatus 41 according to the third embodiment configured in the manner above thus comprises: the high-voltage generator 42 for applying a high voltage to the paint discharged from the rotary atomization head 6; the coating robot 43 on which the rotary atomization head-type coating machine 1 is mounted; and the robot control device 44 for controlling the coating robot 43. The robot control device 44 is then configured to control the coating robot 43 so that the coating distance L from the discharge edge 6D of the rotary atomization head 6 to the coating surface 45A of the object 45 being coated is kept at 90-150 mm. When the coating robot 43 is controlled by means of the robot control device 44 in this way, it is possible to achieve better coating efficiency in relation to the coating surface 45A of the object 45 being coated.

[0096] It should be noted that the third embodiment described an example of the rotary atomization head-type coating machine 1 as a direct-charging electrostatic coating machine which applies a high voltage directly to the paint supplied to the rotary atomization head 6. The present invention is not limited to this embodiment, however, and the present invention may equally be configured for application to a rotary atomization head-type coating machine of the indirect-charging type, which comprises an external electrode for discharging a high voltage at an outer circumferential position of the housing, and applies the high voltage by means of discharge from the external electrode to the paint particles sprayed from the rotary atomization head.

[Key to Symbols]

[0097]

- 1, 31 Rotary atomization head-type coating machine
- 3 Air motor
- 4 Rotary shaft
- 4A Front portion
- 5 Feed tube
- 6 Rotary atomization head
- 6B Outer circumferential surface
- 6C Inner circumferential surface
- 6D Discharge edge
- 6F Front side portion
- 7 Shaping air ring
- 7A Inner cylinder surface
- 7B Front outer cylinder surface (outer cylinder surface)
- 7E Front end portion
- 8 First shaping air jet portion
- 9, 11, 21 Second shaping air jet portion
- 34 Shaping air control device
- 41 Electrostatic coating apparatus
- 42 High-voltage generator
- 43 Coating robot (coating machine movement means)

44 Robot control device (movement means control device)
 45 Object being coated (coating target)
 45A Coating surface
 a Gap dimension
 5 b Set-back dimension
 c Width dimension
 α Angle of front side portion of outer circumferential surface of rotary atomization head
 β Taper angle of front outer cylinder surface
 y Taper angle of imaginary tapered surface
 10 L Coating distance

Claims

15 1. Rotary atomization head-type coating machine comprising: an air motor powered by compressed air;

a hollow rotary shaft which is rotatably supported while extending in a longitudinal direction along an axis of the air motor and has a front end portion protruding from the air motor;
 a feed tube extending through the inside of the rotary shaft as far as the front end portion of the rotary shaft;
 20 a rotary atomization head which is mounted on the front end portion of the rotary shaft and comprises an outer circumferential surface opening out into a cup shape, an inner circumferential surface for diffusing a paint supplied from the feed tube, and a discharge edge positioned at a front end for discharging paint;
 a cylindrical shaping air ring provided on an outer circumferential side of the rotary atomization head; and
 a first shaping air jet portion which is provided on the outer circumferential side of the rotary atomization head and
 25 jets first shaping air toward paint discharged from the discharge edge,

characterized in that

an inner cylinder surface of the shaping air ring is such that at least a front side portion facing the outer
 30 circumferential surface of the rotary atomization head is formed with a uniform inner diameter dimension,
 the first shaping air jet portion is formed as an annular gap between the outer circumferential surface of the rotary atomization head and the inner cylinder surface of the shaping air ring,
 a radial dimension of the gap between the outer circumferential surface of the rotary atomization head and the
 inner cylinder surface of the shaping air ring is set at 0.1-1.0 mm,
 35 a front end portion of the shaping air ring is disposed at a position 0.1-10.0 mm to the rear of the discharge edge of the rotary atomization head,
 a radial width dimension of the front end portion of the shaping air ring is set at 2 mm or less, and
 an outer cylinder surface of the shaping air ring is such that a taper angle opening out from the front end portion of the shaping air ring toward the rear is set at 25° or less in relation to the axis.

2. Rotary atomization head-type coating machine according to Claim 1,

characterized in that a front side portion of the outer circumferential surface of the rotary atomization head facing the inner cylinder surface of the shaping air ring is such that an angle in a direction of decreasing diameter from the discharge edge toward the rear is set at 0-10°.

3. Rotary atomization head-type coating machine according to Claim 1,

characterized in that the shaping air ring comprises a second shaping air jet portion which is positioned radially outside the first shaping air jet portion, is disposed surrounding the rotary atomization head, and jets second
 50 shaping air toward the paint discharged from the discharge edge, and
 the second shaping air jet portion is disposed inside an imaginary tapered surface having a taper angle opening out from the front end portion of the shaping air ring toward the rear of 25°.

4. Rotary atomization head-type coating machine according to Claim 3,

comprising a shaping air control device for controlling a jetting amount of the first shaping air and a jetting amount of the second shaping air,
characterized in that the shaping air control device controls a ratio of the jetting amount of the first shaping air

and the jetting amount of the second shaping air so that a spray pattern of the paint discharged from the rotary atomization head decreases in diameter.

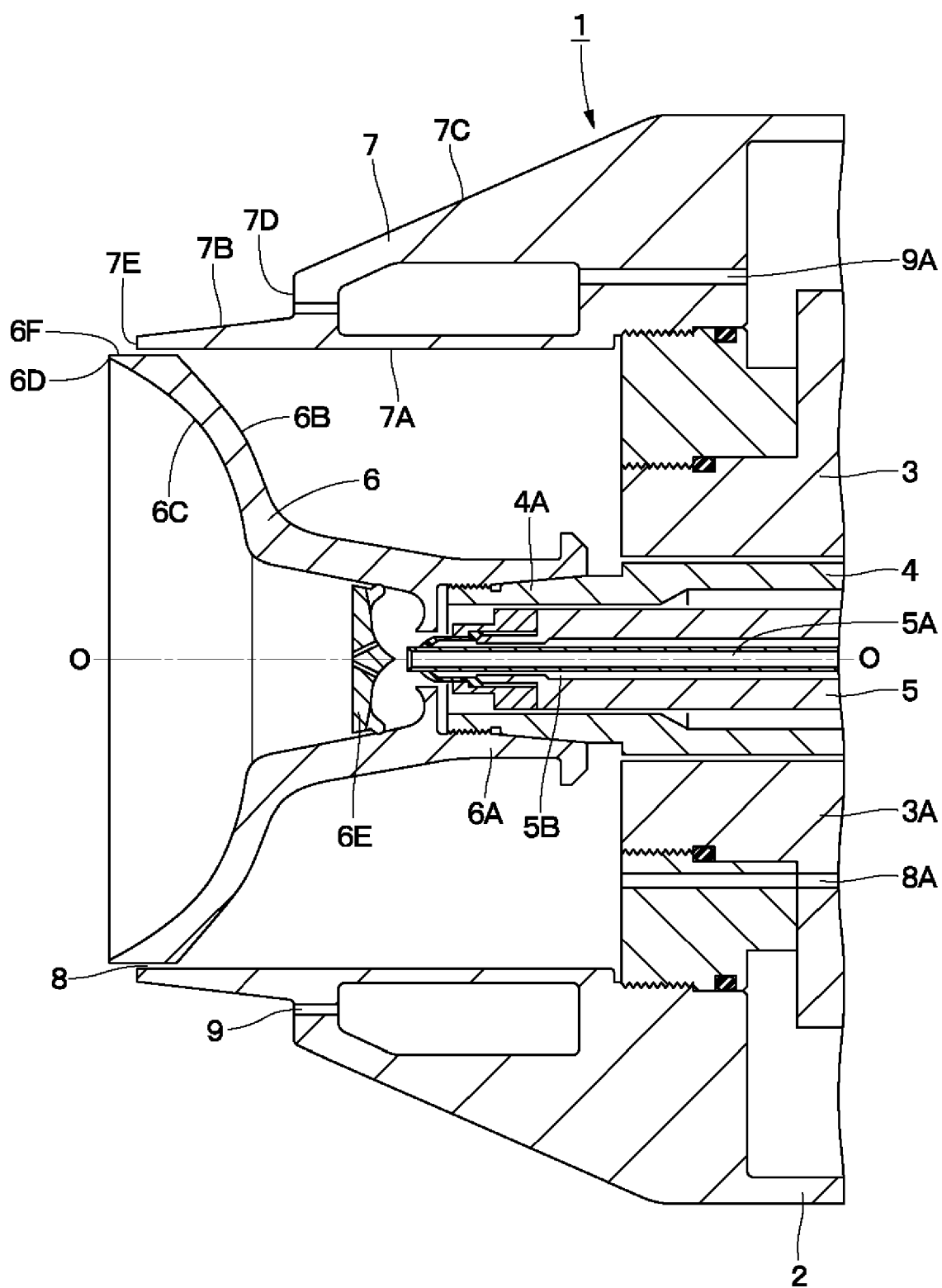
5. Electrostatic coating apparatus comprising the rotary atomization head-type coating machine according to any of Claims 1 to 4, comprising:

a high-voltage generator for applying a high voltage to paint discharged from the rotary atomization head;
a coating machine movement means on which the rotary atomization head-type coating machine is mounted; and
a movement means control device for controlling the coating machine movement means,

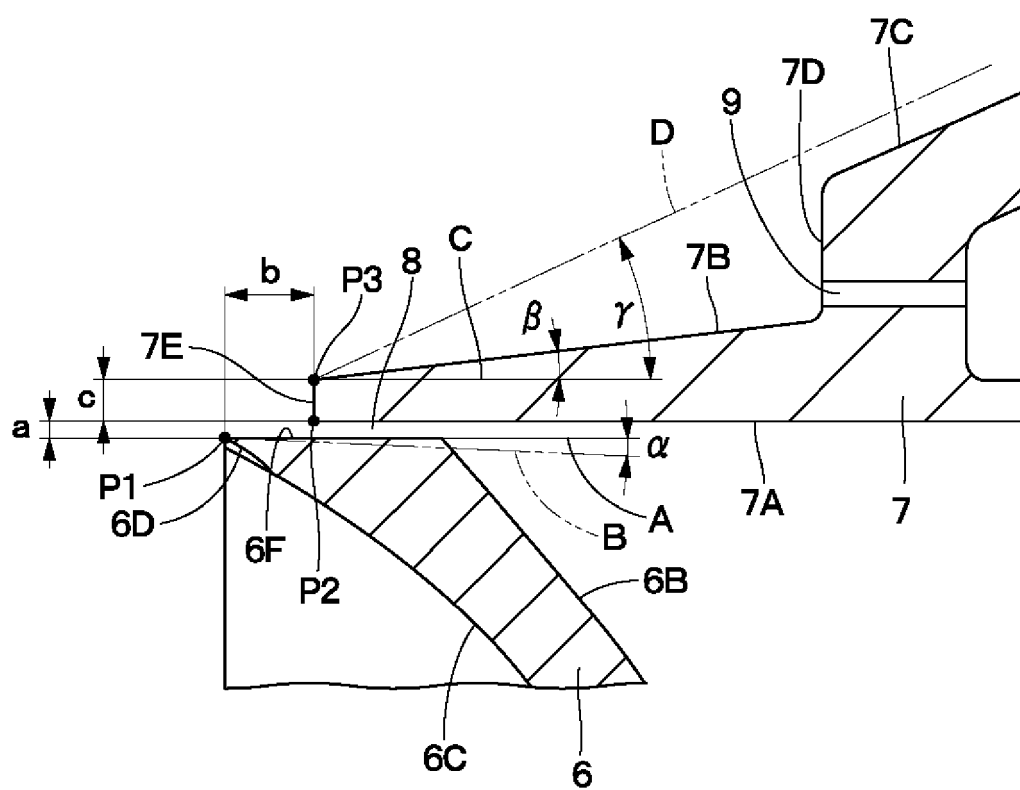
characterized in that

the movement means control device controls the coating machine movement means so that a coating distance from the discharge edge to a coating surface of a coating target is kept at 90-150 mm.

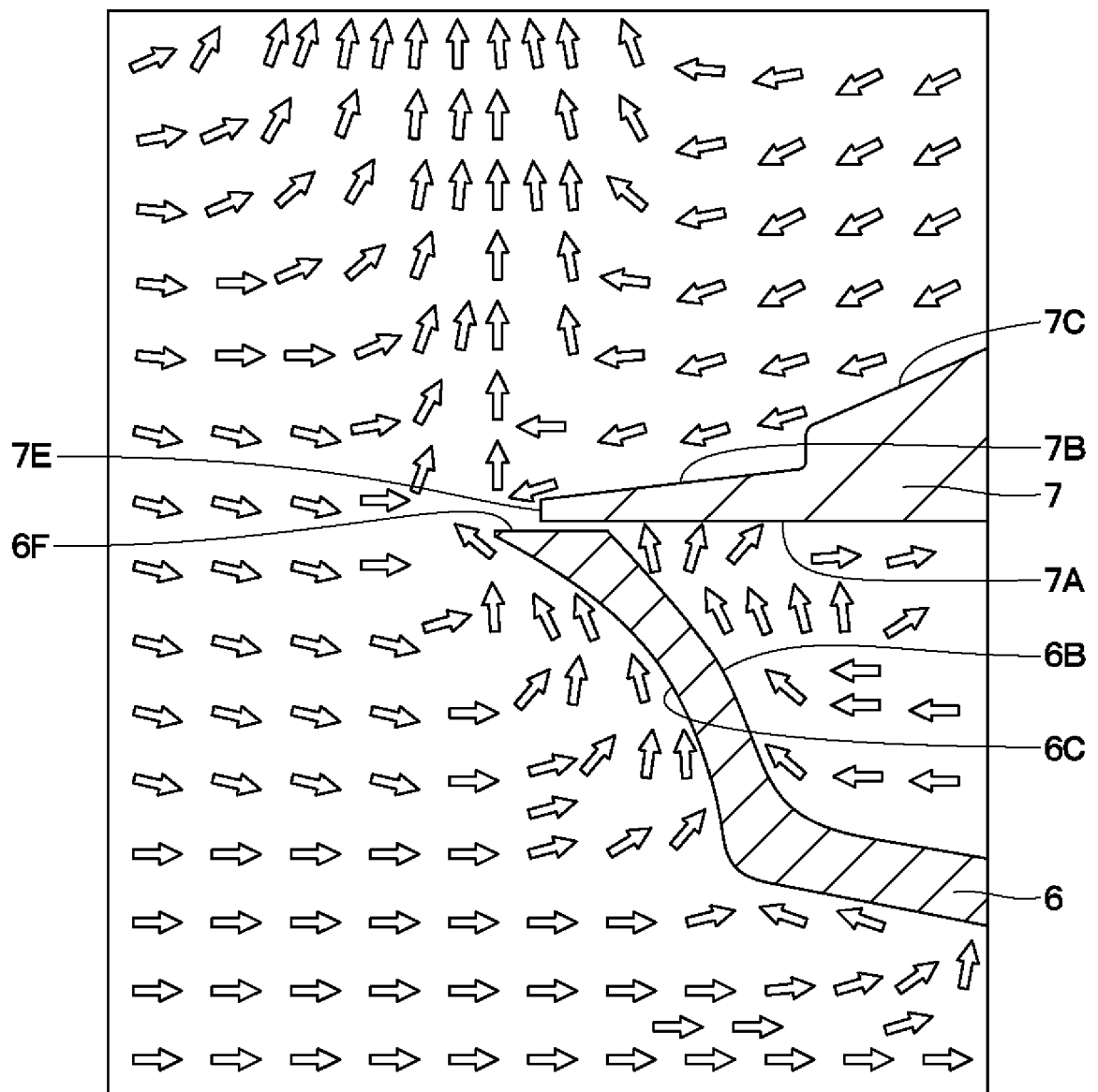
[Fig. 1]



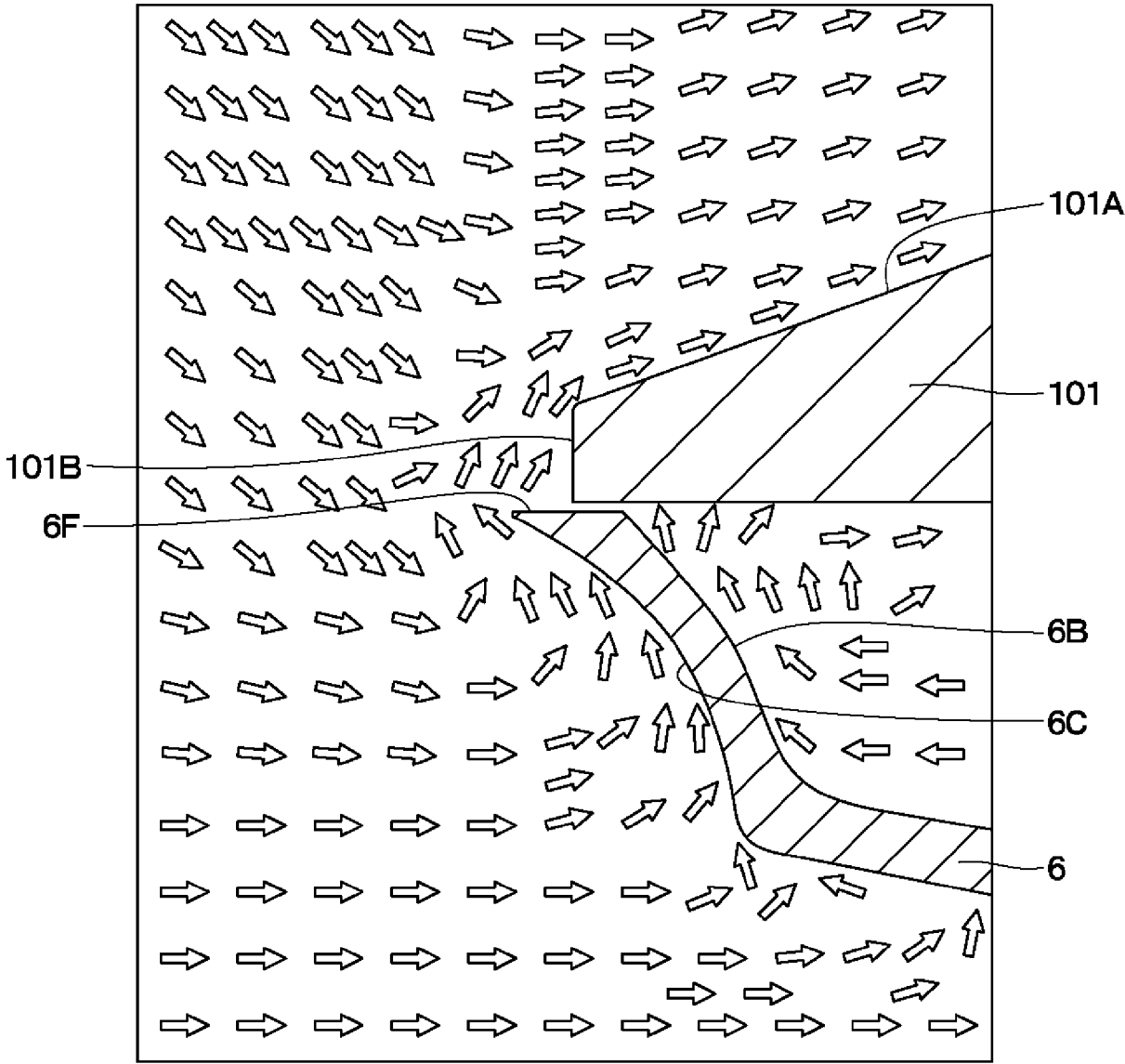
[Fig. 2]



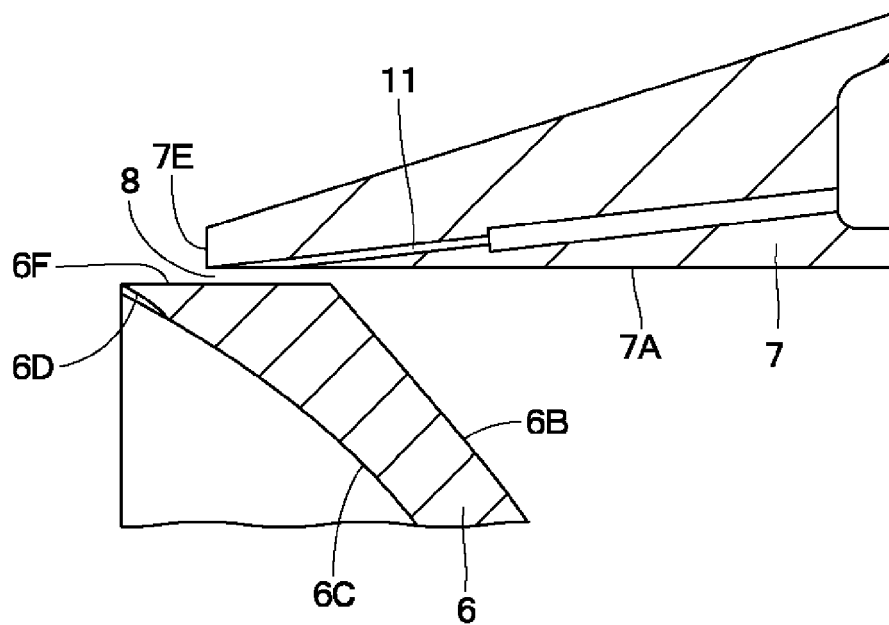
[Fig. 3]



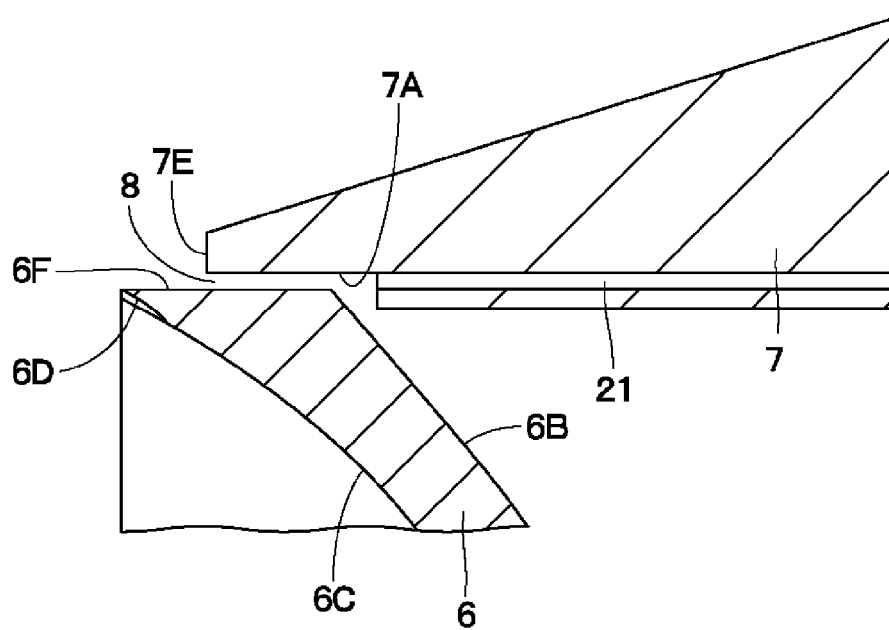
[Fig. 4]



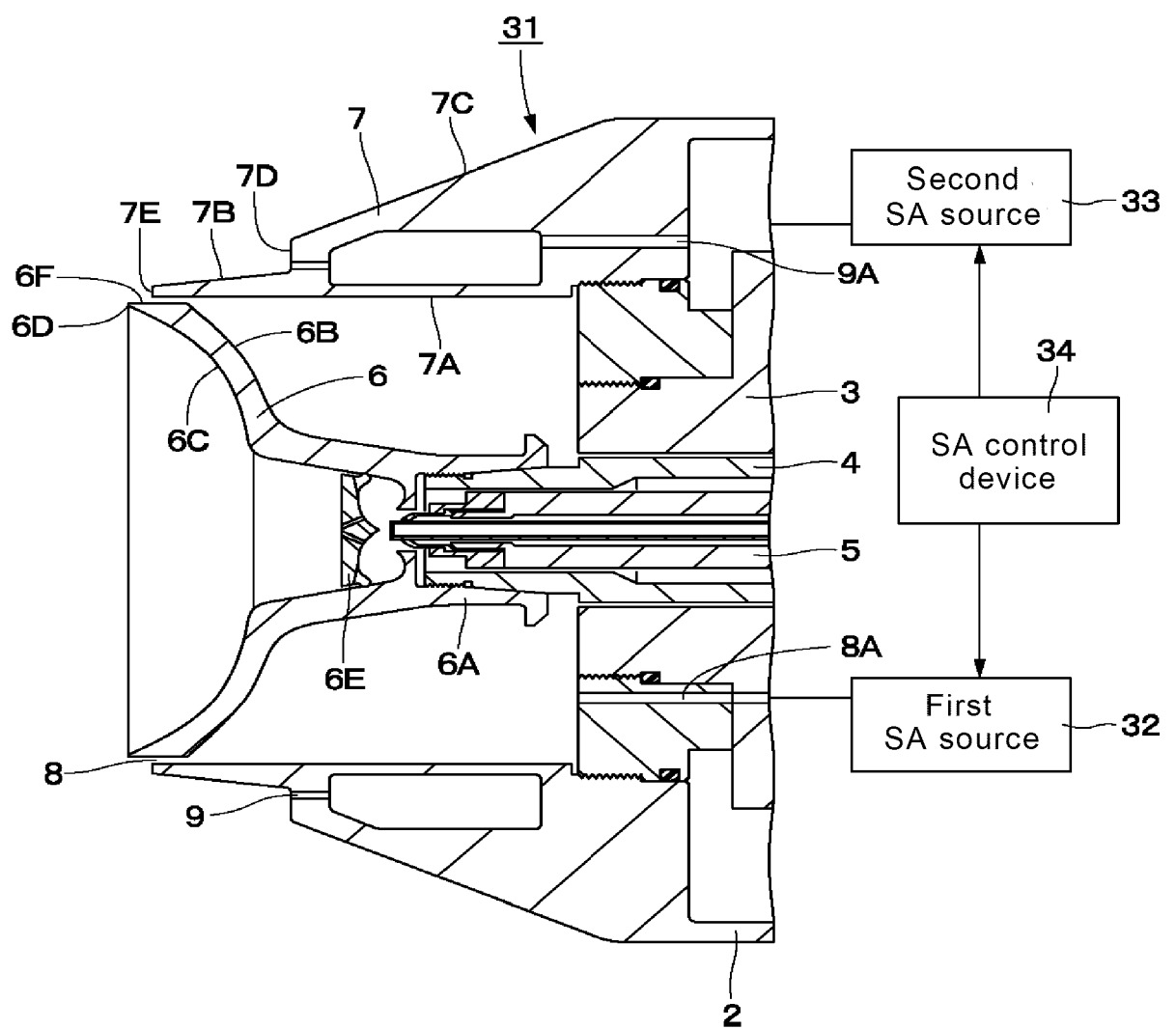
[Fig. 5]



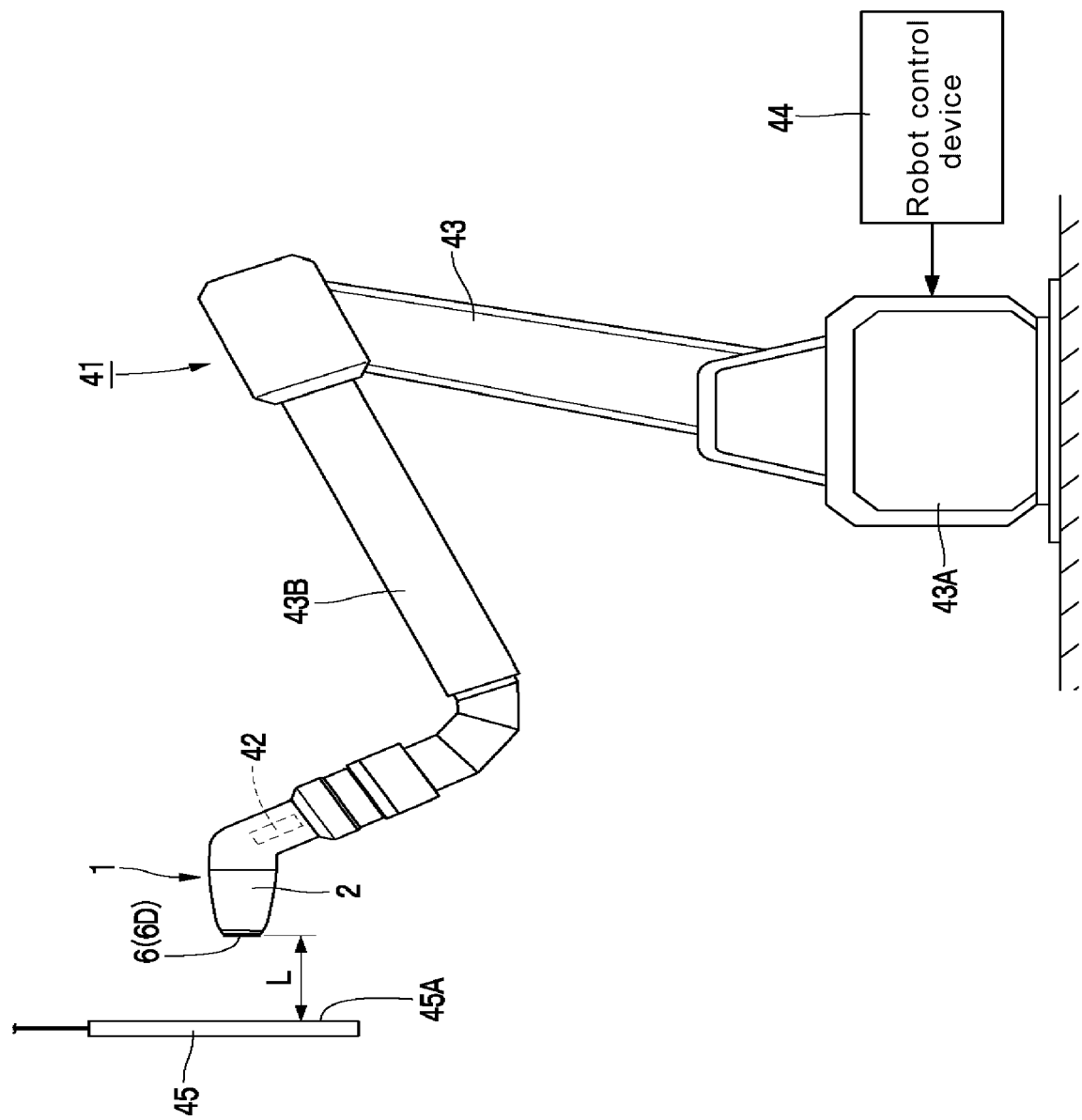
[Fig. 6]



[Fig. 7]



[Fig 8]





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Application Number

EP 24 20 9776

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The present search report has been drawn up for all claims			
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Munich		7 March 2025	Frego, Maria Chiara
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