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(54) METHOD OF CONTINUOUSLY PLATING METAL PLATES.

(57) This invention relates to a plating method consisting of the steps of placing a solid phase plating metal on an object surface of a metal plate being fed, melting the plating metal with the heat of the metal plate, and depositing the molten plating metal in the form of a film on the object metal plate surface. According to this plating method, a molten metal bath is not required at all, and a plating film using a molten metal can be obtained without troubling an operator about various problems arising from a plating operation using a molten metal bath.

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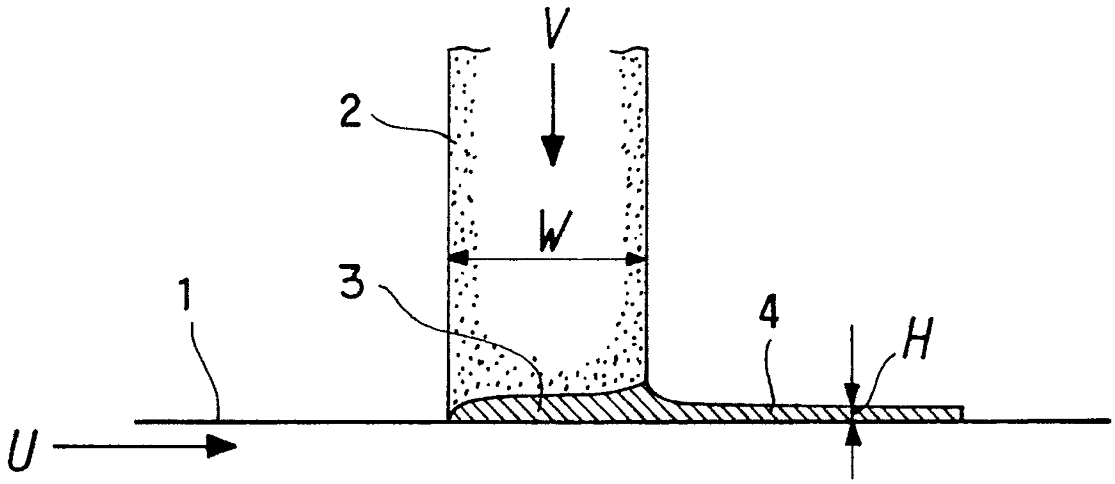
Fig.1



TECHNICAL FIELD

The present invention relates to a method of continuously plating metal sheets on the surfaces thereof without using a hot dip plating bath.

BACKGROUND OF THE INVENTION

Conventionally, hot dip platings where steel strips are immersed in a previously molten plating metal, have been widely practised as methods of forming plated films on the strip surfaces.

A continuous hot dip zinc plating is a representative of this kind of platings. The steel strip is heat-treated in a pre-heating furnace and cleansed off the surface, immersed in a hot dip zinc bath so as to form a plated film, drawn out therefrom, controlled with respect to a plating adhesion amount by means of a gas squeezing, and adjusted on the surface by such as a galvanneal.

The accomplished plated steel sheets have beautiful appearance and excellent corrosion resistances, and are supplied to wide applications.

However existing hot dip zinc platings have various problems about using of the plating baths. Recently, uniformities, smoothnesses and beauties have been more required to the plated surfaces of the steel sheets, mainly in domestic appliances, outer panels of automobiles and others. New sorts of products such as platings different in thicknesses or one-side platings have been demanded. Problems have appeared with respect to the qualities of the hot dip plated steel sheets by the prior art and the plating processes themselves. Severals of such problems are as follows.

1) So-called drosses are much caused in that Fe eluded into the plating bath from the steel surface, or the plating metal is oxidized. Since those must be scooped up and removed, the plating metal is much lost other than adhering to the steel strips.

2) Impurities easily go into the plating bath, since the drosses are generated in the plating bath, or chips of bricks composing pots mix into the plating bath. Those adhere to the steel strip and degrade the strip faces.

3) Since there are differences in a component of plating metal matrix to be supplied into the bath, a component to be adhered to the steel strip and slight elements in the component to be exhausted as by-products outside of the bath, it is difficult to control the bath component to contain necessary elements as predetermined.

Therefore various defects arise in the platings, such as badness in the adhesion amount of the plating, inferiority in the alloying of the galvannealed materials and others.

4) It is necessary to bring steel-made mechanical parts as rolls for passing the strip, arms for supporting the rolls, bearings and others into the plating metal at high temperature and of high corrosion.

Thus, there appear problems of corrosions on these parts, generations of the drosses thereby, and degradations in the plated outer appearances by the corrosion on the outer parts of the rolls in the bath.

In addition, an operation stopping time must be taken for periodically repairing or exchanging the corroded or damaged parts of these mechanical parts, so that the productivities of the facility could not be usefully demonstrated to the maximum.

5) Group grooves of the rolls are easily translated to the plated surfaces by using the passing rolls in the plating bath, and the outer appearance of the strip is damaged.

6) Operators are burdened with heavy and dangerous workings around a good deal of the plating bath at high temperature, such as exhausting of bottomed drosses accumulated at the bath bottom, top drosses at the bath surface, initial passing of the strip into the plating bath, or repairing of the rolls in the bath.

7) Because of only one plating per one pot, it is necessary for different platings to change baths by scooping or prepare in advance a pot dissolving a different sort of plating metal, and move the pot.

8) When a steel material plated on the both sides thereof and that plated on one side are produced in a single apparatus, the plating facility of the pot part must be changed, and it takes many time and labor for changing in addition to the facility load.

9) It is difficult to perform special platings such as the platings of different kinds on the both sides, of multi-layers and of different thicknesses on the both sides.

In view of these conventional hot-dip plating methods, Japanese Patent Laid-Open No. 61-207555 teaches that the nozzle is approached to the running steel strip, and the molten metal supplied from a bath vessel is absorbed by the nozzle due to a wet adhesion between the molten metal and the strip surface, and is applied to the strip.

This method makes use of a coating technique of a paint of high viscosity, and is a practice of feeding the molten metal to the nozzle from the bath vessel, and since the plating adhesion amount is controlled by the head pressure of the molten metal bath vessel, changings in height of the bath surface in the vessel appear as differences in the plating adhesion amount, resulting in a bad accuracy of the plating adhesion amount. Further, since it requires a molten metal vessel corresponding to the plating bath of the immersion type, the problems as stated above are still involved.

Thus, the conventional plating methods have many problems. In view of the above mentioned circumstances, the present invention is to provide a new plating method which may continuously carry out a hot dip plating metal bath as the prior art does, and control the adhesion amount at high precision.

DISCLOSURE OF THE INVENTION

In the present invention, the plating metal is molten by contacting to the moving metal sheet which has been heated to temperature of higher than the melting point of the plating metal material, and the plating metal is continuously fed to the metal sheet, so that the molten plating metal is adhered as a plating film to the surface of the moving metal sheet.

Such a plating method may carry out the plating, not using the molten metal bath at all, and feeds a solid plating metal material to the steel strip to be plated, and melts it on the strip surface by a required plating amount and adheres to the steel strip, whereby the plating adhesion amount may be controlled at a feeding speed of the solid plating metal material, and the plating amount may be secured at a high precision.

In the invention, for securing the melting of the plating metal material, it may be preheated. Further, for uniforming the adhesion amount of the formed plated film, a uniforming treatment may be performed.

BRIEF DESCRIPTION OF THE DRAWINGS

Figs.1 to 4 are explanatory views of basic principles of the present invention;
Figs.5 and 6 show one of embodiments of the inventive method where Fig.5 is a whole perspective view, and Fig.6 is a schematically explanatory view of a plating treating part;
Figs.7 and 8 show another embodiment of the inventive method where Fig.7 is a whole perspective view, and Fig.8 is a schematically explanatory view of the plating treating part;
Figs.9 and 10 show another embodiment of the inventive method where Fig.9 is a whole perspective view, and Fig.10 is a schematically explanatory view of the plating treating part;
Figs.11 and 12 show another embodiment of the inventive method where Fig.11 is a whole perspective view, and Fig.12 is a schematically explanatory view of the plating treating part;
Fig.13 is a perspective view showing another embodiment of the inventive method;
Fig.14 is a perspective view showing another embodiment of the inventive method;
Fig.15 is a plan view showing a plated film formed by the method of Fig.14;
Figs.16 and 17 show another embodiment of the inventive method where Fig.16 is a perspective view, and Fig.17 is a perspective view showing an actually composed example for moving the apparatus in the width of the steel strip;
Figs.18 to 20 show another embodiment of the inventive method where Fig.18 is an explanatory view showing a forming condition of a molten layer by dissolving the plating metal material, Fig.19 is a graph showing a relation between reaction force which the plating metal material receives from the metal sheet and the plating adhesion amount, and Fig.20 is a whole explanatory view of the operating condition;
Figs.21 to 24 show another embodiment of the inventive method where Fig.21 is an explanatory view showing a forming condition of a molten layer by dissolving the plating metal material, Fig.22 is a graph showing influences of dispersions in the temperature of the steel strip, which give to dispersions in Zn plating adhesion amount, Fig.23 is a whole explanatory view of the operating condition, and Fig.24 is an explanatory view showing an interior mechanism of a furnace controlling the temperature of the sheet of Fig.23;
Figs.25a and 25b show another embodiment of the inventive method where Fig.25a is an explanatory view of the operating condition, and Fig.25b is a graph showing transitions of the temperatures of the steel strip and the Zn plated material in this embodiment;
Figs.26 and 27 show another embodiment of the inventive method where Fig.26 is a perspective view of the operating condition, and Fig.27 is a graph showing a transition of the plating adhesion amount when the continuous plating treatment starts up;
Fig.28 is an explanatory view showing another embodiment of the inventive method;
Figs.29 and 30 show another embodiment of the inventive method where Fig.29 is an explanatory view of the operating condition, and Fig.30 is a graph showing a transition of the plating adhesion amount when

changing the plating adhesion amount;
Figs.31 and 32 show another embodiment of the invention where Fig.31 is a whole explanatory view, and Fig.32 is an explanatory view schematically showing the plated condition on one side of the steel strip;
Fig.33 shows another embodiment of the invention which is an explanatory view of schematically showing the plating on one side of the steel strip;
Fig.34 shows another embodiment of the invention which is an explanatory view of schematically showing the plating on one side of the steel strip;
Fig.35 shows another embodiment of the invention which is an explanatory view of schematically showing the plating on one side of the steel strip;
Fig.36 shows another embodiment of the invention which is an explanatory view of schematically showing the plating on one side of the steel strip;
Fig.37 shows another embodiment of the invention which is an explanatory view of schematically showing the plating on one side of the steel strip;
Fig.38 is a perspective view showing the plating condition in the embodiments with respect to the methods of Figs.33 and 36;
Figs.39 to 41 show another embodiment where Fig.39 is an explanatory view of the operating condition, Fig.40 shows schematically cross sections of the plated films formed by this method, Fig.40(A) shows an as-plated condition, Fig.40(B) shows a condition after grinding and Fig.41 is an explanatory view showing positions of the plated metals when performing color platings of stripe by this method;
Fig.42 shows another embodiment of the invention which is an explanatory view of schematically showing the plating on one side of the steel strip;
Fig.43 shows another embodiment of the invention which is an explanatory view of schematically showing the plating on one side of the steel strip; and
Fig.44 shows transitions of the Zn plated adhesion amounts in the present embodiments.

DETAILED DESCRIPTION OF THE INVENTION

Fig.1 schematically shows a principle of the plating method of the present invention, where 1 designates a running steel strip, and 2 designates a plating metal material shaped in a plate to be contacted to the steel strip.

The steel strip 1 is heated to a temperature of higher than the melting point of the plating metal, and the plating metal material 2 is contacted to the steel strip 1 and fed continuously thereto. The plating metal material 2 is molten by a heat conduction from the steel strip 1, and forms a molten layer 3, so that a plated film 4 is formed on the strip with this molten layer 3. The plating metal material 2 is fed in succession to the strip surface in accompany with progressing of the plating, and the plating is continuously formed.

In such a plating method, assuming that the running speed of the steel strip 1 is U, the supplying speed of the plating metal material 2 is V, and the thickness of the plating metal material 2 in the strip running direction is W, a plated film thickness H is given with a formula of

$$H = W(\frac{V}{U}).$$

A predetermined thickness H of the plated film may be therefore formed by making determined the supplying speed in of the plating metal material 2.

When a zinc plating of a plated adhesion amount of 60 g/m^2 (one side) is carried out, and if W = 20 mm, the plating is practised under the conditions of around U = 120 m/min and V = 0.857 mm/sec. In this case, the steel strip is heated around 450°C.

In the invention, for securing the melting of the plating metal material 2, it may be preheated. Fig.2 shows such a practising condition, and 5 is a preheating device of the plating metal material.

For stably providing the thickness of the plated film by the inventive method, it is necessary to secure to a certain degree the thickness of the molten layer 3 formed in that the plating metal material is dissolved by a sensible heat of the steel strip. If the sensible heat of the strip 1 is relatively low with respect to the plating metal material to be used, the molten layer 3 is insufficiently formed so that it is difficult to secure a stable film thickness, and a solid contact between the plating metal material 2 and the strip 1 is remarkable, which causes to destroy the steel strip. If there is a possibility that such a problem seems to occur, the plating metal material 2 is, as seen in Fig.2, preheated by the preheating device 5 for supplying to the strip 1, thereby to enable to accelerate the melting of the plating metal material.

The plated film 4 formed as said above is often caused with differences in the adhesion amount by vibrations of the running strip, and these differences may be uniformed by a surface adjusting device 6 as shown in Fig. 3. As the surface adjusting device, for example, a device with a supersonic vibration system (i.e., a supersonic trowel) having a supersonic vibrator is used. This device is supported by a cylinder device (not shown) having a buffer mechanism, and its vibration plate is slightly contacted to the strip surface formed with the plated film, and the film thickness of the plated metal is uniformed by adding the supersonic vibration to the plated film.

For preventing the differences in the plating adhesion by the vibrations of the strip in the above mentioned plating treatment, the strip 1 may be pinched by pinch rolls 7 at an upflow side than a contacting part of the plating metal material as shown in Fig.4. In such a manner, the differences in plating by the vibration of the strip may be avoided, and collisions between the strip 1 and the plating metal material 2 may be also avoided.

The pinching of the strip by the pinch rolls is better in a near position to the contacting part of the plating metal material 2, in general preferably within 2000 mm (more preferably within 500 mm) in the length of the strip from the above contacting part.

As a preventing means of the adhesion differences (a pinching means) not only said pinch rolls but also an air cushion or an electromagnetic force system are appropriate.

Further, it is preferable to perform the plating treatment by the inventive method in a non-oxidizing astmosphere (e.g., a mixed gas of H_2: 20 to 25% and N_2: 80 to 75%) for securing a plating wettability and adhesion. The surface of the steel strip should be cleansed off before the plating.

The inventive method has various preferable embodiments and modifications as mentioned under for the performance thereof.

Figs.1 to 4 show one side platings of the steel strips. In these platings, there often occur dispersions in the plating amounts by the vibrations of the steel strip. The molten layer 3 of the plating metal exists as seen in Fig.1 between the plating metal material 2 and the strip 1, and for stably providing the thickness of the film 4 , it is necessary to keep this molten layer 3 at a determined distance. However, the passing strip 1 vibrates vertically and the strip displaces in the thickness of the molten layer 3, and subsequently the amount of the plating adhesion is changed.

This problem may be removed by supporting the rear side of the strip to be plated by means of a supporting means. The vibration at the part to be plated is checked by the supporting means and a uniformly plated adhesion may be secured.

Most general supporting means is rolls, and the other appropriate ones may be employed, for example, a gas cushion device of jetting a high pressure gas to the strip surface.

Figs.5 and 6 show an embodiment of using the supporting means.

The plating metal material 2 is fed to the passing steel strip 1 heated to the temperature of higher than the melting point of the plating metal material by a plating metal supply device 10, and molten by contacting to the strip 1, so that the molten plating metal 3 is adhered as the plated film to one side of the strip 1.

The present example uses a roll 8 as the supporting means for a non-plated surface, which supports the rear surface of a plating treatment part A of the strip to be plated.

The plating metal supply device 10 has feed rolls 11 (pinch rolls) for feeding the plating metal material (plate shape) toward the strip surface at a determined speed and the preheater 5 for the plating metal material. Many plating metal materials 2 are set within a holder (not shown) and fed by automatically holding between feed rollers 11 via a feed cylinder (not shown). The plating metal material 2 is fed to the strip surface by a required consuming amount by the feed rollers 11.

The preheating by the pre-heater 5 is for securing the melting of the plating metal material, and is not indispensable.

Figs.7 and 8 show another embodiment of using the supporting means which is a gas cushion device 9 provided with a gas cushion header 12 directing to the strip surface from a nozzle 13 of the header so as to support the strip 1 by this gas.

The supporting means are not limited to the above mentioned ones, and suitable structures may be employed.

Although depending upon the above stated practice, the adhesion amount is often effected with the small differences in the plated film, and these differences may be uniformed by the surface adjusting device 6 as shown in Fig.3. For more effectively preventing the differences caused by the vibrations of the strip, the strip 1 may be pinched by the pinch rolls 7 at the upflow side than a part where the plating metal material contacts as shown in Fig.4.

In Figs.1 to 4, the plating metal material 2 is supplied only to one side of the strip 1. For plating both sides thereof, the plating metal materials 2 are of course placed at the both sides of the steel strip. In this case, it is not necessary to carry out the platings on the both sides at the same positions in the passing line.

Also in performing the platings on the both sides, there arises the problem about non-uniformity in the plating amount caused by the vibrations of the steel strip. This problem is removed by carrying out the respective platings at different positions in the line and supporting the rear side of each of the plating treatment parts.

Similarly to the one side plating as stated above, the most generally available supporting means is the rolls, and other suitable means, for example, the gas cushion device jetting the high pressure gas to the strip surface to support the strip by the gas. In particular, since this gas cushion device supports the strip by non-contacting. Therefore when the plating of one side is performed and the plating of the other side is done at the downflow side, this device is useful as the supporting means for the plated rear side.

Although depending upon this method, the differences in the adhesion amount of the plated metal also more or less occur and may be uniformed by the surface adjusting device 6 as shown in Fig.3 (for example, the supersonic vibration system as stated above).

Thus the steel strip may be supported while uniforming the adhesion amount of the plated surface by using the supporting means having the plated surface adjusting function, especially having the plated surface adjusting function by the supersonic vibration system as said supporting means of the plated part at the downflow side.

Figs.9 and 10 show one of the examples of platings on the both surfaces.

Plating metal supply devices 10a,10b are disposed at different positions in the strip passing line, and the platings are performed respectively. With respect to plate treating parts A,B, the strip 1 is supported by the supporting means at the rear side thereof.

The present embodiment uses a roll 8 as the supporting means of the plate treating part A at the upflow side, and a surface adjusting device 6x of the supersonic vibration system (supersonic vibration trowel) as the supporting means of the plate treating part B at the downflow side. The surface adjusting device 6x is provided as above said with a supersonic vibrator 14, which may uniform tile plating adhesion amount by slightly pressing on the strip surface. The strip surface to be supported by the supporting means at the plate treating part B of the downflow side, is a plated surface. If a distance between the plate treating parts A and B is small, said plating surface is non-solidified, and the roll cannot be therefore used as the supporting means because the surface property is worsened. This embodiment therefore uses the surface adjusting device 6x as the supporting means which may directly contact the plated surface, so that it may simultaneously practise the surface adjustment of the plated side (uniforming the plated adhesion amount) and the supporting of the plate treating part.

In this case, the surface adjustment (treatment by, e.g., said supersonic vibration trowel), by the surface adjusting device 6, on the film formed at the plate treating part B at the downflow side is performed at a further downflow side.

Figs.11 and 12 show another embodiment which uses the gas cushion device 9 as the supporting device of the plate treating part B at the downflow side. The gas cushion device 9 is, as said above, provided with a gas cushion header 12 direting to the steel strip, and the gas is blown to the strip surface from nozzles 13 of the header, so that the strip 1 is supported by this gas. In this example, the plating adhesion amount is uniformed by the surface adjusting devices 6a,6b after platings on the both surfaces.

The supporting means at the plate treating parts may employ various embodiments (structures) and combination. For example, if the plating at the downflow side is carried out after solidification of plated surface at upflow side, the supporting means at the plate treating part B of the downflow side may use the rolls.

Since the differences in the plating adhesion amounts by strip vibrations may be also exactly prevented in the both side plating method as said above, the steel strip 1 may be, as seen in Fig.4, pinched by the pinch rolls 7 at the upflow side than the contacting part of the metal plating material.

One of the problems in practising the inventive plating method is in response to changings in width of the steel strip to be plated. That is, since the plating method of this invention is performed by melting the successively fed solid plating metal material with the heat of the steel strip to be plated, the plating metal material should have almost the same width, as the steel strip.

The plating metal material must be therefore changed in response to the width of the strip, for which a changing device of a large scale is required, and it takes much time for changing the plating metal material in response to the width of the strip, resulting in decreasing a production efficiency.

Fig.13 shows one of the embodiments which may solve such problems, where the plating metal supply device 10 is charged with the plating metal material 2 which is plurally divided in width, and feeds to the strip surface the optional ones of the divided plating metal materials in accordance with the width of the strip to be plated.

In this example, the plating metal material 2 is composed of a center divided material $2a_0$ and both side materials $2a_1$,$2a_2$. To a steel strip of a small width, the center divided material $2a_0$ is used, while the materials $2a_0$,$2a_1$,$2a_2$ are used to a strip of a large width.

For example, when the strip 1 of the small width passes, only the divided material $2a_0$ is supplied to the strip 1, and the other divided materials $2a_1$,$2a_2$ are on standby in the device. When the strip 1 changes to a large wide one, the divided materials $2a_1$,$2a_2$ start to work, and the plating is carried out with the divided materials $2a_0$,$2a_1$,$2a_2$. When the strip 1 again changes to a small wide one, the feedings of the divided materials $2a_1$,$2a_2$ are stopped instantly.

Thus it is possible to rapidly change the plating width in response to the changing in width of the steel strip, since the plating metal material 2 is composed of the divided parts for performing the plating by optionally supplying divided ones, and the non used ones wait for in the device.

In this embodiment, for individually supplying the divided materials, the feed rolls 11 and the pre-heater 5 are divided into parts $11b_0$ to $11b_2$ and $5c_0$ to $5c_2$ respectively in response to the widths of the divided materials. The pre-heaters $5c_0$ to $5c_2$ stop preheating, or lowers the preheating temperature, with respect to the waiting divided materials.

The plated film is also uniformed herein with the surface adjusting device 6x of the supersonic vibration system.

Fig.14 shows an improved embodiment of the method shown in Fig.13. When the plurality of divided materials are supplied to the steel strip 1 in the method of Fig.13, a side edge portion of each of the materials is influenced by thermal conditions from the steel strip, so that there arise dispersions in the plate dissolving amount between clearance gap parts of the divided materials and other parts, resulting in unevenesses of the plate adhesion amount. If the clearance gap is too large, the plate adhesion amount is lacked thereat, or non-plated parts appear.

Fig.14 shows a method for solving such problems, where when the plural divided materials $2a_1$ to $2a_5$ are fed to the strip surface, these materials are vibrated together in the width direction, and the surface uniforming adjustment is performed after the plating treatment.

Shafts of a pair of feed rolls 11 near the steel strip 1 are pivoted at their both sides by chocks 15,16 for supporting two shafts, one 15 of which reciprocates in the width direction by means of a link mechanism comprising a rotating disc 17 and a crank arm 18. The plating metal materials $2a_1$ to $2a_5$ pinched by the feed rolls 11 are therefore supplied to the steel strip 1 as they are vibrating in the width about the strip by the reciprocation of the link mechanism.

Thus, the plating metal materials $2a_1$ to $2a_5$ are supplied as vibrating in the width, the plating film 4 is adhered as snaking to the surface of the steel strip 1, so that each divided part of the plating metal materials $2a_1$ to $2a_5$ is non-plated with the snaking as seen in Fig.15.

If the plated film 4 is added thereafter with the supersonic vibration by the surface adjusting device 6x having the supersonic vibrators 14, the parts 19 non-plated or lacking the plating are covered with the plating films 4 coming from four sides as shown with arrows in Fig.15, and the plated surface is uniformely evened.

According to the inventors' experiments, it is preferable that the vibration amount of the plating metal material is 1/2 of the divided width to maximum, and a frequency is more than 10 Hz for providing a uniform surface by a post surface adjustment. The vibration method is of course not limited to the above mentioned practice.

Fig.16 shows another embodiment (device) which may change the plating width in response to the strip width.

In this device, a plurality of plating metal supply devices are arranged along the strip passing line, and each of the devices may be moved in the width of the steel strip.

According to this device, the plurality of plating metal supply devices are moved to adjust positionings in the strip width, and the plating is performed under covering the whole width of the strip with said plurality of supply devices.

The device of Fig.16 is disposed with the two plating metal supply devices 10A,10B back and forth in the strip passing line.

These plating metal supply devices 10A,10B are arranged so that one of them plates one side in the strip width while the other does the other side, and are movable along the strip width to adjust the positionings.

Fig.17 shows a concrete structual example for moving the plating metal supply device 10 in the strip width, where feed rolls 11 and pre-heaters 5 are attached to a frame 20, which are movably or slidably held on guide rails (not shown) furnished in the strip width via rolls or shoes.

In addition, the frames 20 are provided with pairs of brackets having screwed holes into which screw shafts 23 rotatably supported at external fixtures 22 are fitted, so that each of the devices 10 is moved in the strip width by rotating the screw shaft 23 by a motor 24.

There is disposed the surface adjusting device 6x with the supersonic vibration system at the downflow side than the plating metal supply device 10.

In the above stated device, the plating metal supply devices 10A,10B are adjusted in positionings in response to the strip width for plating as covering the full width of the steel strip.

For example, for carrying out a zinc plating, if the strip width is 630 to 1260 mm and a zinc sheet as the plating metal material is of 30 mm thickness x 630 mm width, it is possible to perform the plating on the strip by arranging the devices 10A,10B as shown in Fig.16 and allowing to move around maximum 315 mm.

Optional number of the plating metal supply device 10 may be disposed as required in the strip passing line.

In the inventive plating method, the plating metal material 2 is fed at a constant speed by a motor, and a slight changing of the feeding speed of the plating metal material 2 gives very large influences to the plating adhesion amount. For exmaple, if the thickness of the plating metal material 2 is 80 mm and the speed of the steel strip to be plated is 2 m/sec, the changing as small as 0.1 mm/sec in the feeding speed creates dispersions of 4 μm in the adhesion amount. These changings in the plating adhesion amount is also caused by vibrations of the steel strip. Changings to a certain extent in the feeding speed of the plating metal material and vibrations of the steel strip to be plated are inevitable in the actual operation, and as a result the plated films of unevened adhesion amount are formed.

This problem may be removed by supplying the plating metal material while it is pressed to the strip such that a predetermined reaction force is effected from the steel strip.

In the inventive plating method, there exists, as shown in Fig.1, the molten layer 3 of the plated metal between the plating metal material 2 and the steel strip 1 to be plated, and for stably forming the film thickness the molten layer 3 should be maintained at a predetermined proper thickness. However the thickness of the molten layer 3 is varied due to changings of the feeding speed of the plating metal material 2 or vibrations of the steel strip 1, and the plated film thickness is dispersed.

In the present method, the plating metal material 2 is fed while pressing it to the steel strip as seen in Fig.18 so that the predetermined reaction force is received from the strip. In this case, the solidified portion of the plating metal material 2 seems to make a metal-contact with the surface of the steel strip 1.

Fig.19 shows a relation between the reaction force f given to the plating metal material 2 and the plating adhesion amount, and the reaction force and the plating adhesion material have a certain relationship, and thus a predetermined amount of the plating adhesion may be provided by feeding the plating metal material such that the reaction force is made fixed. However, if the reaction force is made large exceedingly, the strip is scratched to which attentions should be paid.

In this method, the plating adhesion amount is adjusted with heating temperatures of the steel strip.

Fig.20 shows an actually practising condition of the above mentioned method, where 25 designates heating devices of the steel sheets and 26 designates a charging device (cylinder device) of the plating metal material. Each of the plating metal materials is held between the feed rolls 11 by the charging device 26, and fed (moved) toward the steel strip 1 by the rolls 11.

In this embodiment, the pinch roll 11 of the plating metal material 2 is provided with a torque detector 27 so as to measure as a torque a pressing force of the plating metal material 2 to the strip, and this measured value is fed back to control the feeding amount of the feed rolls 11 for rendering the pressing reaction force always fixed.

According to this method, if the plating of 40 g/m^2 is performed to the steel strip (thickness: 0.8 mm and width: 1220 mm) running at the line speed of 120 m/min, the dispersion of the plating adhesion amount may be controlled within 5%.

The dispersions of the plating adhesion amount are often caused by the changings in the temperature of the steel strip. This will be explained with reference to the schematic view of Fig.21. In the inventive plating method, there exists the molten layer of the plating metal between the plating metal material 2 and the steel strip as said above, and for stably providing the thickness of the plated film it is necessary to maintain the molten layer 3 at a predetermined proper thickness. However, the interface 28 between a solid phase and a liquid phase changes its position by the temperature of the running steel strip to be plated, and when the temperature of the strip is high, the position moves from a solid line to a dotted line in Fig.21. Further, this interface is higher at the downflow side of the line and the molten layer 3 is thicker. When the temperature of the strip becomes higher, the molten layer 3 becomes thicker, and the shape of the liquid phase is made unstable, so that the plating adhesion amount is varied as the time passes. On the other hand, if the temperature of the running steel strip is too low, the plating metal is not so much molten as a desired film thickness can be secured, and in an exceeding case, a non plated state occure.

This problem may be deleted by successively measuring the temperature of the steel strip just before plating and controlling the temperature to be constant.

Fig.22 investigates that the dispersions in the temperature of the steel strip give influences to the dispersions in the plating adhesion amount, taking up an example of Zn plating in the plating method shown in Fig.1, and if the changing in the strip temperature is checked and controlled to be constant, the changing in the plating adhesion amount may be made small.

Fig.23 shows an embodiment that the present invention is applied to a continuous Zn plating of the steel strip, where 29 designates a direct heating furnace which burns oil substances or stains and heats the steel strip to a predetermined temperature, 30 designates a reduction furnace which reduces oxidized film on the strip surface in a reducing atmosphere and performs an annealing, 31 is a cooling furnace which cools the strip in accordance with a given heating cycle, 32 is a strip temperature adjusting furnace for controlling the temperature to be fixed, 33 is a strip tempeature gauge (generally, a radiation thermometer), and 35 is a plating device for performing the inventive plating method.

The steel strip 1 passes the direct heating furnace 29 and the reduction furnace 30, and is cooled until plating temperatures (e.g., around 460°C) in the cooling furnace 31, finally adjusted to a determined temperature in the strip temperature adjusting furnace 32, and sent to the plating device 35. The plating temperature just before plating is detected by the strip temperature gauge 33, and the strip is heated or cooled in the strip temperature adjusting furnace 32 so that the detected values are made fixed.

Fig.24 shows one example of an interior mechanism of the strip temperature adjusting furnace 32, where 36 designates a cooling device provided with slit nozzles 37 for jetting cooling gases (e.g., N_2 gas) and 38 is a heating device (heater), and each of them is used in response to the strip temperature.

The plating adhesion amount is influenced by not only the changings in the strip temperature but also the temperature of the plating metal material. This is why the supplying speed of the plating metal material which governs the plating adhesion amount is changed by the melting speed of the plating metal material, and this melting speed is changed by the strip temperature and the temperature of the plating metal material.

In a system of preheating the plating metal material, the strip temperature is measured immediately before a contacting point, and the heating amount of the plating metal material is controlled in response to the changings in the strip temperature, and the plating adhesion amount may be uniformed by rendering constant a total amount of the sensible heat of the plating metal material and the steel strip.

Fig.25a shows an actually practising condition of the above mentioned method, and the steel strip is preheated to around 500°C by the heating device 25 in an inert or reducing atmosphere, and is sent to the plate treating portion A.

Contacting members (not shown) are contacted to the surfaces of the feeding rolls 11 near the plate treating portion A, and given electricity via a later mentioned electricity control device 39 from an external electric source (not shown), so that a voltage is given to the plating metal material 2 pinched by the feeding rolls 11. The plating metal material 2 is heated at this voltage ignition part of the voltage, and is preheated.

In this embodiment, the radiation thermometer 33x is provided between the plate treating portion A and the heating device 25 for measuring the strip temperature, and the measured value is sent to the electricity control device 39, and this electricity control device 39 controls the electricity to the feeding rolls 11 in accordance with the measured value.

Fig.25b is a graph showing transitions of the measured value (solid line) of the temperature of the steel strip 1 by the radiation thermometer 33x, the temperature (dotted line) of the Zn plated material which varies by controlling of the electricity control device 39, and the melting temperature (one dotted line) of the Zn plated material which is molten by contacting with the steel strip. The temperature of the steel strip 1 which passed the heating device 25 varies relatively moderately, and if the preheating is lacked by this changing, the preheating amount of the Zn plated material is increased to compensate this lacking, and if overheating, the preheating amount thereof is decreased. Thus the melting temperature of the Zn plated material is almost always constant. As a result, the Zn plating adhesion amount may be controlled within a range of ± 10% of an objective value.

Since the strip temperature changed moderately in this embodiment, satisfactory results were obtained by a preheating practice which was less responsible as said above, and even if the temperature of the steel strip 1 intensively changes, the uniform plating may be performed by carrying out the preheating through a high response way such as controlling the preheating temperature by an amount suitable to the changing in the strip temperature by irradiating a high energy as a laser beam to around the contacting points of the Zn plating metal 2.

In general, as heating means for the plating metal materials or metal sheets, such heaters are used as an induction heating device, an infrared heater or a ceramic heater. But since these heating means are relatively delayed in response of the heating control, the plating adhesion amount is dispersed at the time of starting up when the contnuous plating method is practised, or sometimes it is difficult to instanteneously raise and maintain the strip temperature to an objective value when the line speed changes or the plating adhesion amount changes.

Such problems may be solved, for example, by irradiating the high energy beam to the contacting points between the metal sheet and the plating metal material or thereabout so as to effect the heating there.

Fig.26 shows an actually practising condition of said method, which irradiates the laser beam to the contacting point between the steel strip 1 and the plating metal material 2 or thereabout from a laser beam vibrator 40 provided at the upflow side of the line than the plate treating part A. As the laser beam vibrator 40, there are used those systems which combines a vibrator issuing the laser beam with a scanning device which can scan the laser beam within an objective irradiation range, or which is composed of only a vibrator issuing sheet laser beam. It is preferable that the irraditating angle is made vertical with respect to the surface of an object to be irradiated for heightening the energy density as much as possible.

The preheating of the plating metal material by the laser irradiation may be performed in substitution of the pre-heating by the preheater such as the heater or an irradiation heating device. But the preheating by the laser irradiation may depend upon a co-use with the pre-heater as shown in Fig.26. In this case, the laser irradiation is carried out at the times of starting-up of the continuous plating treatment, changing the line speed or changing the plating adhesion amount. At these times, there are sometimes cases that the pre-heating lacks for an objective adhesion amount and the objective adhesion amount cannot be obtained with the preheating only by the pre-heating device 5. By irradiating the laser beam, the irradiated part may be rapidly heated, and the melting of the plating metal may be secured at the time of starting-up of the plating treatment where the melting is insufficient.

Further, it is better that the laser irradiation is maily carried out to preheat the plating metal material. When the plating metal material is molten by the sensible heat of the metal plating sheet, and it is taken into consideration that the dispersion of the plating adhesion amount by the changing in the strip temperature is a big problem, it may be assumed to practise the heating by cancelling the changing in the strip temperature with the laser irradiation and keeping at the fixed temperature, but since its energy is small to an extent of the changing in the strip temperature, a major part of the irradiation energy is given to the plating metal material to be actually molten. An attention should be paid to that if the energy is much irradiated to the metal sheet, the sheet is deformed by the rapid heating and it is undesirable in the operation.

For obtaining the plating adhesion amount of around 40 g/m^2, for example, the energy of the laser beam of around 20 KW is required for irradiation.

Fig.27 shows an improved example of the plating adhesion amount at the starting-up as a result of irradiating the laser beam, where the dotted line shows a case depending upon only the pre-heating device 5 such as the heater, and the solid line shows a case of preheating together with the irradiation of the laser beam. Depending upon the present embodiment, the response of the heating control is enhanced, whereby the plating adhesion amount reaches the objective amount in a very short period of time, and the yielding is heightened. Thus it is apparent that an effect thereby is very high. The irradiation of the laser beam is of course effective to changing of the line speed or increasing of the plate adhesion amount. In any case, it is preferable to control the irradiation so that the irradiating amount gradually decrease as the heating effect by the heating device increases. With respect to changing in the widths of the steel strip 1 and the plating metal material 2, in a case of the laser beam vibrator 40 which scans the laser beam, the irradiation range is controlled by changing the scanning vibration width in response to said changing widths, and in a case of the laser beam vibrator 40 which issues a sheet laser beam, the irradiation range is controlled by sliding the laser beam vibrator back and forth in the line direction.

In other than the irradiation of the laser beam, the high energy can be irradiated by a plasma or an electron beam, but when using the plasma, a sheet plasma vibrator will be used which can issue the plasma in sheet shapes.

Fig.28 shows a method which can carry out the plating without using the above mentioned heating device 5.

As said above, the heating of the plating metal material in general depends upon a high frequent electromagnetic induction device.

However, in the actually operating facility of continuously plating the steel strip, since the width and the thickness of the plating metal material 2 are determined in accordance with the width of the steel strip and an objective amount of the plating adhesion, a coil of the electromagnetic induction device, which surrounds thereabout, should be fairly large to meet the largest size, and the plating operation is undesirable, since the coil does not have the most preferable shape with respect to the plating metal material, and a power source for an electric current is required to issue big outputs. In addition, there arise problems about accidents that the plating metal material directly contacts the coil by vibrations or external shocks, and breaks the heating facility and stops the operation of the line.

Fig.28 shows a method where an electromagnetic induction coil 41 is positioned in opposition to the plating metal material 2 via the steel strip 1 so that the molten layer 3 of the plating metal is heated through the coil 41 by a high frequency induction at the plate treating part A.

According to such a method, since the heating energy may be concentrated to the part of forming the molten layer, the plating metal material may be effectively molten with the sinsible heat of the steel strip 1 and the heating by the coil 41 only without preheating the plating metal material.

In the actual operation, when the steel strip of 1260 mm width and 0,7mm thickness is heated to around 450° C in the heating furnace and is run at the line speed of 60 m/min, it is necessary for obtaining the zinc adhesion amount of around 50 g/m^2 to prepare a device where the frequency of the current flowing to the coil 41 is 20 kHz and the output is controlled within the range of 15 kW.

Fig.29 shows an example suitable to changing of the plating thickness during working of the line.

In the above mentioned plating method of the invention, for changing the plating thickness during the line working, it is necessary to control the heating conditions of the metal sheet and the plating metal material in response to the objective plating adhesion amount, but for decreasing the plating adhesion amount, generally the heating is once stopped to lower the heating temperature and the cooling is done by leaving in the air. Therefore a high response to the cooling cannot be expected. When the plating adhesion amount decreases, there occur such parts (non-steady part) where the objective plating adhesion amount cannot be reached at once, and a problem of bad yielding arises.

In view of such a problem, a method shown in Fig.29 may forcibly flow a cooling gas to the surfaces of the steel strip and/or the plating metal material 2, so that the steel strip and/or the plating metal material are cooled by presence or absence of the gas flowing layer and controlling the gas flowing amount when the gas flowing layer is formed.

Depending upon the embodiment shown in Fig.29, while the plating metal material 2 passes the pre-heating device (not shown) and reaches the contacting point with the steel strip 1, the plating metal material is surrounded with box bodies 42 having gas passages 43 therewithin and is continuously fed.

The box bodies 42 have tubular partitions 44 therewithin where the plating metal material 2 passes at the interior sides of the tubular partitions 44. Gas passages 43 are formed at inner and outer sides of the partition 44, and the cooling gas (generally N_2) flows in arrow directions.

The cooling gas cools at first the plating metal material 2 nearly the contact point between the steel strip and the plating metal material, and then cools as running up along the surface of the plating metal material. If the cooling gas is flown into the gas passage 43 as required, the plating metal material may be fully cooled before reaching the contacting point. One part of the cooling gas goes out to the steel strip from the lower part of the box body 42.

Experiments were made on decreasing the amount of the zinc plating adhesion by using the above device. As shown in Fig.30, for decreasing 80 g/m^2 of the plating adhesion amount to 40 g/m^2, when the pre-heating of the plating metal material 2 (zinc) was stopped and cooled by leaving in the air (solid line), 30 minutes were taken, and on the other hand in the present embodiemnt, when N_2 gas was flown at the average flowing speed of 3 m/sec into the gas passage 43 (dotted line), the plating adhesion amount could be decreased to the objective adhesion amount in about 15 minutes. The steel strip 1 may be cooled instead of the plating metal material 2.

As methods of heating the plating metal material, there are various ways of high response (for example, irradiating the high energy beam as the laser beam), and the plating adhesion amount can be changed at high efficiency by using them together with these methods.

One of the problems in carrying out the inventive method is dispersions in the adhering amount of the plating metal. In the above mentioned plating method which does not employ the hot dip plating bath, the dispersions are easily caused by the strip vibrations. In the plating method by molten metal, the adhesion amount of the plating metal is adjusted by means of an air squeezing or others after plating, but conventional adjusting devices could not display a sufficient adjusting function on such parts of the plating adhesion less than an objective amount. Said method therefore supplies the plating metal more than the objective amount, and an excessive metal is removed.

However since the excessive plating metal is molten, it flows to the upflow side than the adjusting device of the plate adhesion amount and a part thereof drops and splashes to cause troubles by striking the plated surface of the strip.

According to methods shown in Figs.31 to 37, it is possible to exactly adjust the plating adhesion amount without causing troubles as splashing of the excessive plating.

Figs.31 and 32 show one of these examples. There is provided a gas squeezing nozzle 45 for adjusting the plating adhesion amount at the downflow side than the plate treating part of the passing strip (the upper side in this example), so that the excessive plating metal of the plated film 4 is blown off by the gas jetting from said nozzle, thereby to adjust the plating adhesion amount. The removed metal flows downward, that is, the upflow side of the pass line of the strip.

In this example, a sensor 48 such as a range finder successively measures the thickness of the plated metal 47 of a drop part by the excessive plating metal at the upflow side than of an amount adjusting part 46 of the plating metal adhesion by the gas squeezing nozzle. In accordance with measured values by the sensor 48, the supply amount of the plating metal at the plate treating part, i.e., that of the plating metal material 2 in this example, is controlled. Actually, an optimum range of the thickness of a plated metal 47 is predetermined, and a feed control (ON-OFF control or a feed amount control) of the plating metal 2 is carrid out, so that the measured values are set therein. For example, when the value measured by the sensor 48 reaches an upper limit, the supply of the plating metal 2 is stopped, and when the thickness decreases and reaches a certain determined value (lower limit), the plating metal material 2 is fed again at a constant speed.

Thus the plating adhesion amount may be exactly adjusted without generating extremely excessive plating metal.

Fig.33 shows an example using a supersonic system as the adhesion amount adjuster (the same as the surface adjuster shown in Fig.9), and the same controlling is made here.

Fig.34 shows another system where sensors 48a,48b detect a drop end 49 of the excessive metal from the adhesion amount adjusting part 46 so as to control the feed of the plating metal material 2 in accordance with said detection.

Actually, the drop end 49 of the excessive metal is detected by the sensors 48a,48b such as the range finder and the feed control of the plating metal material 2 (ON-OFF control or the feed amount control) is carried out so that said end falls within a range (X) between the sensors 48a,48b. For example, the feed of the plating metal material 2 is stopped at the time of detecting the drop end 49 by the sensor 48a, and then at the time when the excessive plating metal amount decreases and the drop end 49 is detected by the sensor 48b, the control is made so as to feed again the plating material 2 at a determined speed.

In the above stated method, the controlling of the adhesion amount of the plating metal is not limited, and appropriate practices other than the gas squeezing or the supersonic vibration system may be employed.

In addition to said control of the feed amount of the plating metal, the thickness of the plated metal is measured at the downflow side of the line direction than the adjusting part of the metal adhesion amount, it is possible to control the film thickness at the adjusting part of the adhesion amount in accordance with the measured values. According to such a system, in addition to said system, the film thickness is also measured at the downflow side than the adjusting part of the adhesion amount, and therefore the control may be made at a higher precision.

Figs.35 to 37 show that thicknesses of the plated films are measured successively by the sensors 50 at the downflow side than the adhesion adjusting amount part 46, and the film thicknesses are controlled in accordance with the measured values. That is, a feed gas pressure is controlled in a case of the gas squeezing nozzle 45, and a pressure of a vibration plate 51 is controlled in a case of the supersonic vibration system, so that the measured values fall into allowable ranges.

Since other subjects are the same as Figs.32 to 34, explanations therefor will be omitted.

The zinc plating was performed on the steel strip with the facility shown in Fig.38. In this embodiment, the both surfaces of the steel strip 1 were plated by supplying the plating metal material 2, but the illustration shows the plating on one surface.

The plating adhesion amount adjusting device was the supersonic vibration system.

A laser range finder 48' was positioned at the downflow side than the plate treating part, and the thickness of the plated metal was successively measured. In accordance with the measured values, ON-OFF control was made on the supply of the plating metal material 2 such that the thickness of the plated metal including the excessive zinc was 0.5 to 3 mm. As a result, the plated film uniform at 20 to 80 g/m^2 of the adhesion amount was obtained without causing any troubles by the excessive zinc.

The laser range finder 48" was also disposed at the downflow side than the plating adhesion amount adjusting device, and this range finder measured the thickness of the plated film, and when a vibrating board 51 was controlled in accordance with the measured values, the dispersions in said adhesion amount of 20 to 80 g/m^2 could be reduced about 10 to 15%.

The inventive plating methods are applicable to various metal or alloy platings, for example, it is possible to perform the platings on the steel strips such as not only Zn plating, Al-Zn alloy plating, but also Co-Cr-Zn alloy plating (e.g., 1%Co - 1%Cr - Zn alloy plating), Al-Mg-Zn alloy plating (e.g., 5%Al - 0.6%Mg - Zn alloy plating). Al-Si-Zn alloy plating (e.g., 55%Al - 1.6% Si - Zn alloy plating), Si-Al alloy plating (e.g., 10%Si - Al alloy plating), Sn-Pb alloy plating (e.g., 10%Sn - Pb alloy plating).

The present invention is especially suited to productions of Zn-Ni alloy plated steel sheets and Zn-Fe alloy plated steel sheets which have been used widely as rust resistance for automobiles, and Zn-Mn alloy plated sheets, which are seen hopeful as rust resistance for automobiles in a coming age.

Needs have recently become more demanded for rust resistant steel sheets having high corrosion resistability, mainly laying stresses on automobiles. In the zinc plated steel sheets, the high corrosion resistance may be secured by increasing the plating amount, but too much amount deteriorates processability (powdering resistance) and weldability, and a problem about scrap treatment occurs. In view of these circumstances, developments have been made on alloy electroplated steel sheets having excellent resistability. Among them, since Zn-Fe alloy plated steel sheet and Zn-Ni alloy plated steel sheets are excellent in faculties such as paint adhesion, corrosion resistance and others, those have been widely used as the rust resistant steel sheets for the automobiles. Since Zn-Mn alloy plated steel sheets are also excellent in the paint adhesion and corrosion resistance, it is promised as the rust resistant steel sheets of the automobiles in the coming age.

However, these alloy plated steel sheets have such defects that electrolyzing efficiency is relatively low and production costs are high. For satisfying the needs of the high corrosion resistance which has recently become higher, those alloy platings must secure plated amounts of a certain extent, and plated steel sheets securing the plated amount are very expensive.

With respect to the Fe-Zn alloy plated steel strip, alloyed hot dip zinc plated steel strips have conventionally been produced which were subjected to an alloying heat treatment immediately after the hot dip zin plating, and have widely been used as the rust proof steel sheets for the automobiles. However, in this kind of plated steel sheet, when the plating adhesion amount is more than 60 g/m^2, a Γ phase is made thick and the processability is extremely lowered.

On the other hand, according to the inventive method, it is possible to produce each of the above mentioned alloy plated steel sheets without bringing about the problems as said.

The melting points of Zn-Fe alloy, Zn-Ni alloy and Zn-Mn alloy are higher than that of zinc, and it is almost impossible in view of melting corrosions of the rolls in the plating bath to operate such alloy platings in the practice having the molten pot. Rare cases have made studies on faculties of the above alloy plated steel sheets.

The inventors have developed the present inventive method which may industrially practise the platings by the molten metals with respect to alloys of high melting points, and it has been possible to produce each of the above mentioned alloy plated steel sheets. Following facts have been proved in the studies on the properties of their plated steel sheets.

Zn-Fe alloy plate steel sheet:

This plated steel sheet has corrosion resistance of higher degree after plating in comparison with the electrodeposited steel sheets and the alloyed hot dip plated steel sheets which have the same plating adhesion amounts and Fe contents, and further it has more excellent processability than the alloyed hot dip plated steel sheet. Reasons therefor are not always apparent, but sucn assumptions may be taken that with respect to the corrosion resistance after the coating, in the plated sheet of the invention, a part of zinc in the surface layer evaporates in a process after the plating and a Fe enriched film is formed, so that Fe thereby improves the property of a phosphate film formed by the pre-treatment of the coating, and with respect to the processability, the alloyed hot dip zinc plating has a mixed structure of ζ phase, δ_1 phase and Γ phase, and on the other hand, the inventive plated steel sheet has the same uniformed structure as the electrodeposited Zn-Fe plating.

Zn-Ni alloy plated steel sheet:

This plated steel sheet has the corrosion resistances of higher degree (bare corrosion resistance and corrosion resistance after the coating) in comparison with the electrodeposited steel sheet which has the same plating adhesion amount and Ni content. The reasons therefor are not always apparent, but such assumptions may be taken that a part of zinc in the surface layer evaporates in a cooling process after the plating and a Ni enriched layer is formed, and this layer effectively acts on the corrosion resistance.

Zn-Mn alloy plated steel sheets:

This plated steel sheet has the corrosion resistances of higher degree (bare corrosion resistance and corrosion resistance after the coating) in comparison with the electrodeposited steel sheet which has the same plating adhesion amount and Mn content. The reasons therefor are not always apparent, but such assumptions may be made that a thermally non-equilibrium phase is formed in the plated film of the electrodeposited Zn-Mn alloy plating, while a thermaly equilibrium phase is formed in a plated film of the molten Zn-Mn alloy plating, and this phase will effectively act on the corrosion resistance.

According to the present invention, each of the alloy plated steel sheets is produced by supplying, as the plating metal materials, Zn-Fe alloy material, Zn-Ni alloy material and Zn-Mn alloy material to the steel sheets 1 as shown in Fig.1 and the followings.

In the above mentioned plating treatments, plating metal materials are used where alloying element contents are specified as follows.

Zn-Fe alloy plating: Zn-Fe alloy material of Fe being not more than 60 wt%,
Zn-Ni alloy plating: Zn-Ni alloy material of Ni being not more than 30 wt%, and
Ni-Mn alloy plating: Zn-Mn alloy material of Mn being not more than 60 wt%.

Accordingly, the alloy plated steel sheets to be produced are formed with plated films almost corresponding to the above alloying ratios. In the Zn-Fe alloy plating, if Fe content

In the Zn-Fe alloy plating, if Fe content is more than 60 wt%, the melting point of the alloyed material is made too high, and it is difficult to provide an appropriate melting condition, and a victim corrosion resisting action to steel sheets is deteriorated. It is preferable to set the lower limit of Fe content to be 3 wt% for securing the corrosion resistance after the coating.

In the Zn-Ni alloy plating, if Ni content is more than 30 wt%, the melting point of the alloyed material is made too high, and it is difficult to provide an appropriate melting condition. Although the Ni content exceeds 30 wt%, it is scarecely effective to the corrosion resistance, and not only it is disadvatageous in view of the cost, but also the victim corrosion resistance to the steel sheets is lowered, resulting in easily causing red rusts. It is preferable to set the lower limit of Ni content to be 5 wt% for securing a determined corrosion resistance.

In the Zn-Mn alloy plating, if Mn content is more than 60 wt%, the melting point of the alloyed material is made too high and it is difficult to provide an appropriate melting condition. Although the Mn content exceeds 60 wt%, it is scarecely effective to the corrosion resistance, and it is disadvantageous in view of the cost. It is preferable to set the lower limit of Mn content to be 10 wt% for securing desired corrosion resistance.

In addition to advantages of the functions as said above, the steel sheets of the invention may be produced at very low costs in comparison with the electrodeposition.

In addition, the inventive method uses a plating metal material which is dispersed with grains in the metal or the alloy, whereby a plated film dispersed with the grains may be produced. In the conventional practising hot dip plating, since it was difficult to uniformly disperse the grains in the bath, the grains could not be uniformly dispersed in the film, and it was impossible to produce steel sheets dispersed with this kind of grains. On the other hand, the inventive method melts the plating metal material by contacting it to the strip to be plated, so that it is possible to obtain a plated film uniformly dispersed with the grains by using the plating metal material cast with the dispersed grains.

For the purposes of dispersing the grains in the plated film, such improvements may be assumed of the paint adhesion, corrosion resistance, lubricity, wear resistance, etc., and grains to be used are inorganic grains, organic grains, organic-inorganic combined grains or their mixted grains. For example, appropriate grains may be used of SiO_2, Al_2O_3, TiO_2, ZrO_2, Cr_2O_3, CrO_3, $ZnCrO_3$, $BaCrO_3$, $MgCrO_3$, BN, SiC, WC, TiN, MoS_2, diamond, various kinds of resins (Teflon, PEEK, polyimideamide, silicon resin, boron resin, etc).

In the inventive method, if using colored pigments, colored plated steel strips may be obtained. The prior art has been known which colors the plated surface of the strip by utilizing chemical reactions, but the thus obtained strip has a colored layer in the surface only, and if the plated surface is hurt, the colored layer is delaminated to spoil the outer appearance.

For producing the colored plated steel sheet according to the invention, the plating metal material dispersed with the coloring pigment is continuously fed to the steel strip as shown in Fig.1 and the followings so as to form a plated film, and after the plated film is solidified, the plated film is ground.

This will be explained, referring to Fig.39.

The plating metal material 2 is a cast one as a sheet or a block which has been uniformly dispersed with the coloring pigment in the plating metal (or alloy).

Since the plating metal material 2 is molten on the strip surface and adhered there as it is, the coloring pigment dispersed in the plating metal material is disperded as it is in the plated film 4. Fig.40(A) schematically shows the cross section of the plated film where 52 designates the plated metal (or alloy) and 53 designates the pigment grains.

Since the molten plated metal and the pigment grains 53 are inferior in wettability, many pigment grains 53 in the surface layer of the plated film are rejected by the molten metal and do not adhere to the plated surface but drop out. The pigment grains 53 are therefore scarecely exposed on the surface of the plated surface 4, and no coloring by the pigment is seen on the strip surface. Thereupon, in the inventive method, after the plated film is solidified, a grinding device 54 polishes (grinds) the plated surface to expose the pigment grains 53 in the plated film as seen in Fig.40(B), thereby to color the strip surface.

As the grinding device 54, appropriate means such as grinding rolls as brushing rolls may be employed.

Since the formed plated film 4 is instantly solidified, there may be provided a cooling device (an air cooling device, etc) at the upflow side than the grinding device 54.

In the present method, if a plurality of plating metal materials 2 having different coloring pigments are disposed with respect to the width of the steel strip 1 as shown in Fig.41, for supplying it to the strip surface, it is possible to produce colored plated films like stripes.

For a purpose of securing the corrosion resistance of the plated film produced by the present method, one or plural layers of modified treatments such as the chromate, silicate, phosphate, organic complicated silicate treatments may be formed. Further, in view of objects, such clear coatings are possible, aiming at gloss, semi-gloss, de-luster or super de-luster. The steel sheet by this method may be employed as a substrate of a pre-coat or a post-coat steel sheets.

Table 1 shows the plating conditions and the colors of the plated steel strips when the color platings are operated by the inventive method.

Table 1

Plating Metal Material (Block)		Heating Temp. of Strip (°C)	Plating Adhesion Amount (g/m²)	Colors
Composition	Preheating Temp. (°C)			
20% carbon (pigment)-Zn	410	450	60	Black
30% titanium oxide (pigment)-Zn	"	"	"	White
20% red iron oxide (pigment) -Zn	"	"	"	Red
10% iron blue (pigment)-Zn	"	"	"	Blue
20% fluorescent pigment -Zn	"	"	"	Fluorescent

Further, in the present invention, multi-layered platings are possible by contacting the plating metal materials 2 of homogeneous or heterogeneous sorts to the steel strip back and forth in the strip passing direction.

Various kinds of new plated steel sheets have recently been demanded, and one of them is an ultra thick plated sheet, or a multi-layered steel sheet by the heterogeneous sort (including alloys and the same in the followings).

As the methods of forming the plated film on the steel strips, there have conventionally been the hot dip plating where the steel sheet is immersed into the molten metal bath, and the electroplating. If the plated steel sheets as said above are produced in dependence upon the prior art, following problems will occur.

In the hot dip plating method, since a balance limit exists between a viscosity that the plating metal in the bath is upheaved and a gravity that the plating metal drops, the plating adhesion amount is limited accordingly. If the adhesion amount is made much exceedingly, the plated surface is drop and the outer appearance of the steel sheet will be deteriorated. The plated thickness obtained by the ordinary hot dip plating method has a certain limit. There is a method of practising more than twice of the hot dip platings (multi-layered plating) for providing the ultra thick plating or the plated film of the heterogeneous sort. If the multi-layered plating is performed in the hot dip plating method, the facility is made large scaled and the cost thereof is too high. Among the plural layered platings composed of the heterogeneous plating metals, there are some kinds impossoble to be produced. In the multi-layered platings that the melting point of the lower plated layer is lower than that of the upper plated layer, the plated film of the lower layer is molten when the upper layer is plated. The plating of such a combination is impossible.

On the other hand, the ultra thick plated steel sheet by the electroplating has a demerit of high production cost. Furthermore, in the production of the multi-layered sheet composed of the heterogeneous plated metal films, a water-washing facility is required for preventing the plating composition from going into other plating bath, so that a facility cost is made high. In addition, there are technical and economical restraints in the kinds of plating available metals and embodiments.

According to the present invention, the multi-layered platings are possible in dependence upon the molten metal without inviting the above mentioned problems.

Fig.42 shows one of the examples of the multi-layered plating treatments according to the inventive method, where a first plated layer is formed at a plate treating part A to the passing steel strip 1 heated to a temperature higher than the melting point of the plating metal. That is, a plating metal material 2a is supplied to the passing heated steel strip 1 from a plating metal supply device 10 and is molten by contacting to the steel strip 1, and a molten plating metal 3a is continuously adhered as a plated film 4a of the first layer to the surface of the passing steel strip 1.

The plated film 4a of the thus treated strip 1 is solidified by a cooling device 55 (a gas cooling device), and subsequently the same plate treatment as above is carried out at a plate treating part B and a plated film 4b of a second layer is formed. The second layered plated film can be exactly formed, only when the first layered plated film is solidified, and therefore the cooling and the solidification of the plated film 4a prior to the plating of the second layer are necessary conditions.

In order that the plating metal material 2b is molten at the plate treating part B, it is necessary that the first layered plated film 4a and the steel strip 1 have temperatures higher than the melting point of the plating metal material 2b, and the plating may be performed at the plate treating part B only to such metals having melting points lower than that of the plating metal of the first layer. As the multi-layered plated steel sheets of the above mentioned combination, there are, for example, steel strips composed of the first layer being Zn plated film and the second layer being Al-Mg-Zn plated film (e.g., 5%Al-0.6%Mg-Zn alloy).

The steel strip 1 and the first layered plated film 4a should maintain the temperatures higher than the melting point of the plating metal material 2a also at the plate treating part B, for which an attention should be paid so that the cooling by the cooling device 55 does not lower the temperatures of the steel strip 1 and the plated film 4a than the melting point of the plating metal material 2a. For compensating the lowering of the temperature of the steel strip by the plating of the first layer, a heating device may be provided between the plate treating parts A and B for heating the strip 1 as required.

Fig.43 shows that the first layered plate treatment depends upon the inventive method, and the second layered plate treatment depends upon the other practice. With respect to the plating of the second layer, the plating metal material 2a is continuously charged into a plating metal supply device 10' which has a plating metal dissolving device 56 facing to the strip passing line, so that a tip of the plating metal material 2a is molten in succession, and the molten plating metal 3a is adhered as a plated metal 4a to the surface of the passing strip.

Since the employed plating method does not melt the plating metal material with the sensible heat of the steel strip, the temperatures of the strip 1 and the first layered plated film 4a are not necessary to be higher than the melting point of the plating metal material 2b when the second layer is plated.

The inventive method may therefore realize, without problems, the multi-layered platings of such a combination that the melting point of the second layer is higher than that of the first layer, and of the plating metals of the same kinds. As an example of the former, the multi-layered steel strip has the first layer of Fe (15 to 20%) - Zn alloy plated film excellent in a victim corrosion resistance and the second layer of Fe (60 to 80%) - Zn alloy plated film suitable as a substrate to be coated. The ultra thick plated steel strip may be produced by coating the multi-layers with the plating metal of the same kind as the latter does.

The plating metal supply device 10' is provided with a feed roll 57, a pre-heating device 58 of the plating metal material, and a dissolving device 56.

The dissolving device 56 is a tubular body having heating bodies 59 (heater) circumferentially thereof, formed with a nozzle 60 at one end side in a manner that a nozzle outlet 600 is approached nearly to the surface of the passing strip. The plating metal material 2 preheated by the pre-heater 58 is fed into the dissolving device 56 from an opening at the other side, and its tip is dissolved in succession, and the molten metal 3 thereby is supplied to the strip surface and the plated film is formed.

In the inventive method, the plating may be carried out on the steel strip at room temperatures, but it is preferable to heat the strip 1 to a predetermined temperature to prevent occurrences of bad shaping of the strip by rapid solidification of the molten metal. The heating devices are used, as required, at the upflow sides than the plate treating parts.

At each of the plate treating parts, the plating metal material 2 to be charged into the plating metal supply device 10' is generally shaped in plate, but, for example, powders may be sufficient.

In the present invention, the multi-layered plated films composed of more than two layers may be formed by providing the plate treating parts at more than two positions. The plated films may be combined at disposal as stated above. For example, the lower layer may be the Zn film, while the upper layer may be the colored plated film containing the coloring pigment or the multi-layered plated film including the different grains for the corrosion resistance.

Further, in the inventive method, the steel strip 1 may run other than horizonally, for example, vertically. In a vertical line, the strip may run irrespective of up and down directions.

When plating the both surfaces of the strip according to the invention, it is possible to easily practise the platings of the heterogeneous sorts on the respective surfaces of the strip by positioning the plating metal materials of the different compositions at the both sides of the strip. For example, as a blank sheet of an outer panel for the home electric appliances, a Fe-Zn alloy plated film is formed on one side (for coating side) and Zn plated film is formed on the other side (bare side).

By the present invention, it is possible to continuously form the plated film on the metal sheet, not using the hot dip plating bath, and the under mentioned merits are brought about in comparison with the prior art using the plating bath.

1) The plating metal is not lost other than adhering to the steel strip, since no dross is generated as using the plating bath.

2) The outer appearance is kept beautiful without staining drosses or impurities to the strip surface.

3) Almost the same component as the plating metal material is plated because the plating metal material is directly deposited, and the component in the plated film is uniformed and is easily controlled accordingly.

4) Any mechanical parts are not immersed in the bath, so that the operation is not stopped for exchanging or repairing the corroded mechanical parts.

5) Any rolls are not used in the bath, and the roll grooves are not translated to the outer plated surface of the strip.

6) It is not necessary to exhaust the bottom and top drosses, initially pass the strip into the bath, and repair the rolls in the bath, whereby the burden on the oeprators is considerably reduced.

7) For practising the alloy platings, it is sufficient to only exchange the plating metal material to be supplied to the steel strip, and the large operations are not required as changing the bath or moving the pot, and the platings of various kinds are available.

8) It is possible to easily operate the one-side plating, the multi-layered platings, the thickness different platings of the both sides, and the heterogeneous platings of the both sides by selecting and changing the positionings of the plating metal material, the supplying embodiment and speed of the plating metal material.

In addition to them, since the solid plating metal is fed toward the steel strip to be plated, and molten by a required plating amount at the strip surface, the plating adhesion amount may be controlled by the feeding speed of the solid plating metal material, and therefore the adhesion amount at the high precision may be secured.

EXAMPLES

(I) For carrying out the Zn plate on the steel strip by the inventive method, the steel strip (1.6 mm thickess) moving at various speeds is heated 450°C, to which the zinc sheet (the plating metal material) at the room temperature is contacted as shown in Fig.1, and the transmissions of the Zn plating adhesion amount are investigated. Fig.44 shows results thereof, where the zinc sheet deprives the heat of the steel strip and heights the temperature, and is molten a few seconds later, and adhered at constant adhering amounts. In this example, the zinc sheet is supplied by melting as much as the sensible heat of the steel strip can do.

(II) Table 2 shows the plating conditions and the characteristics of the plated steel strips where alloyed platings are carried out on the steel strips according to the inventive method.

Table 2

Plating Metal Materials (Block)		Heating Temp. of Strip (°C)	Plating Adhesion Amount (g/m^2)	A	B	C	D
Composition	Preheating Temp. (°C)						
1%Co-1%Cr-Zn	410	600	60	○	○	×	○
5%Al-0.6%Mn-Zn	370	450	"	◎	◎	×	○
55%Al-1.6%Si-Zn	450	600	"	◎	△	○	△
10%Si-Al	550	600	"	◎	△	◎	◎
10%Sn-Pb	280	330	"	◎	×	×	◎

Note
A: Corrosion Resistance
B: Coating
C: Heat Resistance
D: Processability

(III) Table 3 shows the plating conditions and the usage of the obtained steel strips where the grain dispersion platings are carried out on the steel strips.

Table 3

Plating Metal Materials (Block)		Heating Temp. of Strip (°C)	Plating Adhesion Amount (g/m2)	Usage
Composition	Preheating Temp. (°C)			
20%$ZnCrO_3$-Zn	410	450	60	Super high corrosion resistance
10%$BaCrO_3$-5%SiO_2-Zn	410	450	"	Super high corrosion resistance
30%SiO_2-Zn	410	450	"	Substrate to be coated
30%Al_2O_3-Zn	410	450	"	Substrate to be coated
30%Teflon-13%Ni-Zn	480	600	"	Lubricity
5%MoS_2-Zn	410	450	"	Lubricity
20%SiC-13%Ni-Zn	480	600	"	Abrasion resistance
10%WC-13%Ni-Zn	480	600	"	Abration resistance

(IV) The Zn-Fe alloy plated steel sheets are produced as shown in Table 4 according to the inventive method. The corrosion resistances, processabilities and producing costs of the obtained steel sheets are appreciated and shown in Table 4 in comparison with the conventional electrodeposited Zn-Fe alloy plated steel sheets and the alloyed molten zinc plated steel sheets.

The Zn-Ni alloy plated steel sheets are produced as shown in Table 5 according to the inventive method. The corrosion resistances and producing costs of the produced steel sheets are appreciated and shown in Table 5 in compariosn with the conventional electrodeposited Zn-Ni alloy plated steel sheets.

The Zn-Mn alloy plated steel sheet are produced as shown in Table 6 according to the inventive method. The corrosion resistances and producing costs of the produced steel sheets are appreciated and shown in Table 6 in comparison with the conventional electrodeposited Zn-Mn alloy plated steel sheets.

Table 4

	Plating Metal Materials		Temp. of strip (°C)	Plating Adhesion Amount (g/m²)	D	F	G
	Composition	Heating (Preheating) °C					
Inventive Materials	Zn-25%Fe	750	800	60	○	◎	◎
	Zn-20%Fe	660	700	60	○	◎	◎
	Zn-10%Fe	660	700	60	○	◎	◎
Comparative Materials	Alloyed molten Zn-15%Fe	-	-	60	×	○	◎
	Alloyed molten Zn-10%Fe	-	-	60	△	○	◎
	Electrodeposited Zn-20%Fe	-	-	60	○	○	△
	Electrodeposited Zn-10%Fe	-	-	60	○	△	△

Note D: Processability
F: Corrosion Resistance after Coating
G: Cost

Table 5

	Plating Metal Materials		Temp. of Strip (°C)	Plating Adhesion Amount (g/m^2)	H (hr)	F	G
	Composition	Heating (Preheating) °C					
Inventive Materials	Zn-10%Ni	485	850	40	500	◎	◎
	Zn-13%Ni	485	850	40	500	◎	◎
	Zn-15%Ni	600	850	40	450	◎	◎
Comparative Materials	Molten zinc	-	-	60	100	×	○
	Alloyed molten zinc	-	-	60	100	△	○
	Electrodeposited Zn-13%Ni	-	-	40	350	○	△

Note. F: Corrosion Resistance after Coating
G: Cost
H: Time for Red Rust Appearing SST

Table 6

	Plating Metal Materials		Temp. of Strip (°C)	Plating Adhesion Amount (g/m^2)	H (hr)	F	G
	Composition	Heating (Preheat-ing) °C					
Inventive Materials	Zn-30%Mn	680	820	40	1,500	◎	◎
	Zn-35%Mn	740	850	40	2,000	◎	◎
	Zn-40%Mn	780	850	40	2,500	◎	◎
Comparative Materials	Molten Zinc	-	-	60	100	×	○
	Alloyed Molten Zinc	-	-	60	100	△	○
	Electrodeposited Zn-40%Mn	-	-	40	1,500	○	△

Note F: Corrosion Resistance after Coating
G: Cost
H: Time for Red Rust Appearing SST

In the examples, the corrosion resistance after coating is appreciated with respect to the blister resistance, poring resistance and corrosion resistance after chipping.

With respect to the blister resistance, the test pieces are subjected to the phosphate treatment by immersion and the cation electrodeposition coating of 20 µm, and are marked with cross cuts, and subjected to the salt spray test, and after a predetermined time passes, the occurrence of the blister is appreciated.

With respect to the poring resistance, the test pieces which have been prepared in the same manner as the test pieces in the blister resistance, are corroded in the combined cycle test, and are appreciated by measuring depths of corrosion of the substrates after cleaning off the coatings and the corrosion generators.

If the outside of the outer panel of the automobile body is hurt in the coated film by chipping, corrosions advance therefrom. Based on this assumption, the test pieces of the three coatings are chipped with the graverometer to hurt the coatings, and the corrosion resistances are tested with the salt spray test.

(V) Table 7 shows the plating conditions where the multi-layer platings are formed on the steel strips according to the present invention.

Table 7

First Layer Plate (Plate Treating Part A)				Second Layer Plate (Plate Treating Part B)					
Plating Metal Materials		I	J	Plating Metal Materials		I	J	L	K
Composition	Heating (Preheat-ing) °C	(°C)	(g/m²)	Composition	Heating (Preheat-ing) °C	(°C)	(g/m²)	(g/m²)	
Zn	410	450	240	Zn	420	410	240	480	Fig.42
10%Fe- Zn	650	700	40	40%Mn-Zn	840	630	20	60	"
55%Al-1.6%Si-Zn	450	600	90	10%-SiO_2-Zn	410	450	30	120	Fig.43

Note I: Temperature of Steel Strip
J: Plating Adhesion Amount per One Side
K: Plating Practices
L: Total Plating Adhesion Amount per One Side

INDUSTRIAL APPLICABILITY

The present invention may be widely applied in substitution for the conventional continuous hot dip zinc plating method, and utilized to almost all of the continuous platings other than the zinc, and may easily produce Zn-Fe, Zn-Ni and Zn-Mn alloy plated steel sheets which have conventionally been impossile to treat the plating with the hot dip pot.

Claims

1. A method of continuously plating metal sheets, characterized by melting a plating metal material by contacting to a moving metal sheet heated to a temperature higher than a melting point of the plating metal material, and continuously supplying the plating metal material to the metal sheet thereby to continuously adhere said molten plating metal as a plating film to the surface of the moving metal sheet.

2. A method as claimed in claim 1, characterized by contacting a preheated plating metal material to the metal sheet.

3. A method as claimed in claim 1, characterized by practising at least one of under items (i) to (v) for producing a plated film of a uniform thickness;
   i) carrying out a uniforming treatment of the adhering amount of the plated film after having formed the plated film,
   ii) pinching the metal sheet by pinching means of a contact type or a con-contact type at an upflow side than a contacting part of the plating metal material so as to prevent vibrations of the passing metal sheet,
   iii) supplying the plating metal material to the metal sheet as pressing thereto so as to always receive a determined reaction force from the metal sheet,
   iv) continuously measuring a temperature of the metal sheet just before plating so as to control said temperature to be constant, and
   v) measuring the temperature of the metal sheet just before the contacting part of the plating metal material and controlling a heating amount of the plating metal material in response to changings of the sheet temperature, thereby to make constant a total amount of a sensible heat of the plating metal material and the metal sheet at the contacting part thereof.

4. A method as claimed in claim 2, characterized by practising at least one of under items (i) to (v) for producing a plated film of a uniform thickness;
   i) carrying out a uniforming treatment of the adhering amount of the plated film after having formed the plated film,
   ii) pinching the metal sheet by pinching means of a contact type or a non-contact type at an upflow side than a contacting part of the plating metal material so as to prevent vibrations of the passing metal sheet,
   iii) supplying the plating metal material to the metal sheet as pressing thereto so as to always receive a determined reaction force from the metal sheet,
   iv) continuously measuring a temperature of the metal sheet just before plating so as to control said temperature to be constant, and
   v) measuring the temperature of the metal sheet just before the contacting part of the plating metal material and controlling a heating amount of the plating metal material in response to changings of the sheet temperature, thereby to make constant a total amount of a sensible heat of the plating metal material and the metal sheet at the contacting part thereof.

5. A method claimed in claim 1, characterized by carrying out the plating as supporting the rear side of the metal sheet contacted with the plating metal material by means of supporting means, thereby to continuously plate one side of the metal sheet.

6. A method claimed in claim 2, characterized by carrying out the plating as supporting the rear side of the metal sheet contacted with the plating metal material by means of supporting means, thereby to continuously plate one side of the metal sheet.

7. A method as claimed in claim 5, characterized by practising at least one of under items (i) to (v) for producing a plated film of a uniform thickness;
   i) carrying out a uniforming treatment of the adhering amount of the plated film after having formed the plated film,

ii) pinching the metal sheet by pinching means of a contact type or a non-contact type at an upflow side than a contacting part of the plating metal material so as to prevent vibrations of the passing metal sheet,
iii) supplying the plating metal material to the metal sheet as pressing thereto so as to always receive a determined reaction force from the metal sheet,
iv) continuously measuring a temperature of the metal sheet just before plating so as to control said temperature to be constant, and
v) measuring the temperature of the metal sheet just before the contacting part of the plating metal material and controlling a heating amount of the plating metal material in response to changings of the sheet temperature, thereby to make constant a total amount of a sensile heat of the plating metal material and the metal sheet at the contacting part thereof.

8. A method as claimed in claim 6, characterized by practising at least one of under items (i) to (v) for producing a plated film of a uniform thickness;
i) carrying out a uniforming treatment of the adhering amount of the plated film after having formed the plated film,
ii) pinching the metal sheet by pinching means of a contact type or a non-contact type at an upflow side than a contacting type of the plating metal material so as to prevent vibrations of the passing metal sheet,
iii) supplying the plating metal material to the metal sheet as pressing thereto so as to always receive a determined reaction force from the metal sheet,
iv) continuously measuring a temperature of the metal sheet just before plating so as to control said temperature to be constant, and
v) measuring the temperature of the metal sheet just before the contacting part of the plating metal material and controlling a heating amount of the plating metal material in response to changings of the sheet temperature, thereby to make constant a total amount of a sensible heat of the plating metal material and the metal sheet at the contacting part thereof.

9. A method of continuously plating metal sheets, for continuously plating the metal sheet on the both sides thereof according to the method of claim 1, characterized by carrying out the plating treatments to the metal sheet on the respective parts thereof with the plating metal materials at different positions in the sheet passing line, and supporting the metal sheet on its rear sides at the respective plate treating parts by means of a supporting means.

10. A method as claimed in claim 9, characterized in that the supporting means in the plate treating part at the down flow side of the sheet passing line, has the surface adjusting function.

11. A method as claimed in claim 2, for continuously plating the metal sheet on the both sides thereof, characterized by carrying out the plating treatments to the metal sheet on the respective parts thereof with the plating metal materials at different positions in the sheet passing line, and supporting the metal sheet on its rear sides at the respective plate treating parts by means of a supporting means.

12. A method as claimed in claim 11, characterized in that the supporting means in the plate treating part at the down flow side of the sheet passing line, has the surface adjusting function.

13. A method as claimed in claim 9, characterized by practising at least one of under items (i) to (v) for producing a plated film of a uniform thickness;
i) carrying out a uniforming treatment of the adhering amount of the plated film after having formed the plated film,
ii) pinching the metal sheet by pinching means of a contact type or a non-contact type at an upflow side than a contacting part of the plating metal material so as to prevent vibrations of the passing metal sheet,
iii) supplying the plating metal material to the metal sheet as pressing thereto so as to always receive a determined reaction force from the metal sheet,
iv) continuously measuring a temperature of the metal sheet just before plating so as to control said temperature to be constant, and
v) measuring the temperature of the metal sheet just before the contacting part of the plating metal material and controlling a heating amount of the plating metal material in response to changings of

the sheet temperature, thereby to make constant a total amount of a sensible heat of the plating metal material and the metal sheet at the contacting part thereof.

14. A method as claimed in claim 9, characterized by practising at least one of under items (i) to (v) for producing a plated film of a uniform thickness;
i) carrying out a uniforming treatment of the adhering amount of the plated film after having formed the plated film,
ii) pinching the metal sheet by pinching means of a contact type or a non-contact type at an upflow side than a contacting part part of the plating metal material so as to prevent vibrations of the passing metal sheet,
iii) supplying the plating metal material to the metal sheet as pressing thereto so as to always receive a determined reaction force from the metal sheet,
iv) continuously measuring a temperature of the metal sheet just before plating so as to control said temperature to be constant, and
v) measuring the temperature of the metal sheet just before the contacting part of the plating metal material and controlling a heating amount of the plating metal material in response to changings of the sheet temperature, thereby to make constant a total amount of a sensible heat of the plating metal material and the metal sheet at the contacting part thereof.

15. A method as claimed in claim 1, characterized by charging plating metal materials plurally divided in width into a device for supplying the plating metal material toward the metal sheet, and supplying to the surface of the metal sheet the optional ones of the divided plating metal materials in accordance with the width of the metal sheet to be plated.

16. A method as claimed in claim 2, characterized by charging plating metal materials plurally divided in width into a device for supplying the plating metal material toward the metal sheet, and supplying to the surface of the metal sheet the optional ones of the divided plating metal materials in accordance with the width of the metal sheet to be plated.

17. A method as claimed in claim 15, characterized by practising at least one of under items (i) to (v) for producing a plated film of a uniform thickness;
i) carrying out a uniforming treatment of the adhering amount of the plated film after having formed the plated film,
ii) pinching the metal sheet by pinching means of a contact type or a non-contact type at an upflow side than a contacting part part of the plating metal material so as to prevent vibrations of the passing metal sheet,
iii) supplying the plating metal material to the metal sheet as pressing thereto so as to always receive a determined reaction force from the metal sheet,
iv) continuously measuring a temperature of the metal sheet just before plating so as to control said temperature to be constant, and
v) measuring the temperature of the metal sheet just before the contacting part of the plating metal material and controlling a heating amount of the plating metal material in response to changings of the sheet temperature, thereby to make constant a total amount of a sensible heat of the plating metal material and the metal sheet at the contacting part thereof.

18. A method as claimed in claim 16, characterized by practising at least one of under items (i) to (v) for producing a plated film of a uniform thickness;
i) carrying out a uniforming treatment of the adhering amount of the plated film after having formed the plated film,
ii) pinching the metal sheet by pinching means of a contact type or a non-contact type at an upflow side than a contacting part part of the plating metal material so as to prevent vibrations of the passing metal sheet,
iii) supplying the plating metal material to the metal sheet as pressing thereto so as to always receive a determined reaction force from the metal sheet,
iv) continuously measuring a temperature of the metal sheet just before plating so as to control said temperature to be constant, and
v) measuring the temperature of the metal sheet just before the contacting part of the plating metal material and controlling a heating amount of the plating metal material in response to changings of

the sheet temperature, thereby to make constant a total amount of a sensible heat of the plating metal material and the metal sheet at the contacting part thereof.

19. A method as claimed in claim 1, characterized by supplying the plurality of divided plating metal materials to the metal sheet while vibrating the divided plating metal materials and performing the uniforming treatment of the adhesion amount of the plated film after having formed the plated film.

20. A method as claimed in claim 16, characterized by supplying the plurality of divided plating metal materials to the metal sheet while vibrating the divided plating metal materials, and performing the uniforming treatment of the adhesion amount of the plated film after having formed the plated film.

21. A method as claimed in claim 1, characterized by providing a plurality of devices for supplying the plating metal materials toward the metal sheet in the metal passing line, making said devices movable in width of the metal sheet, and selecting positions of said devices in the width direction of the metal sheet, thereby to supply the plating metal material to the full width of the metal sheet.

22. A method as claimed in claim 2, characterized by providing a plurality of devices for supplying the plating metal materials toward the metal sheet in the metal passing line, making said devices movable in width of the metal sheet, and selecting positions of said devices in the width direction of the metal sheet, thereby to supply the plating metal material to the full width of the metal sheet.

23. A method as claimed in claim 1, characterized by irradiating a high energy beam to the contacting point between the metal sheet and the plating metal material or a vicinity thereof so as to heat the metal sheet or the plating metal material or the both thereof at said contacting point or said vicinity.

24. A method as claimed in claim 23, characterized by mainly irradiating the high energy beam to the plating metal material so as to preheat it.

25. A method as claimed in claim 23, characterized by using a laser beam as the high energy beam to be irradiated.

26. A method as claimed in claim 23, characterized by using an electronbeam as the high energy beam to be irradiated.

27. A method as claimed in claim 23, characterized by using a plasma as the high energy beam to be irradiated.

28. A method as claimed in claim 1, characterized by providing an electromagnetic induction coil in opposition to the plating metal material via the metal sheet and effecting a high frequency induction heat by the coil in a molten layer of the plating metal at the plate treating part.

29. A method as claimed in claim 2, characterized by enabling to forcibly flow a cooling gas to the surfaces of the metal sheet and/or the plating metal material, and controlling the temperatures of the metal sheet and/or the plating metal material by the presence or absence of the gas flowing layer and adjusting the gas flowing amount when said gas flowing layer is formed.

30. A method as claimed in claim 1, characterized by adjusting the plate adhesion amount after having formed the plated film, measuring, at the upflow side in the line than the adjusting part of the plated adhesion amount, the thickness of the plated metal including an excess plated metal brought from said adjusting part of the plate adhesion amount, and controlling the supplying amount of the plating metal at the plate treating parts in accordance with said measured value.

31. A method as claimed in claim 1, characterized by adjusting the plate adhesion amount after having formed the plated film, detecting an end of a drop part of the excess plated metal brought from said adjusting part of the plate adhesion amount at the upflow side of the line than the adjusting part of the plate adhesion amount, and controlling the supplying amount of the plating metal at the plate treating parts in accordance with said detection.

32. A method as claimed in claim 1, characterized by controlling the plate adhesion amount after having formed the plated film, measuring, at the upflow side in the line than the adjusting part of the plated adhesion amount, the thickness of the plated metal including an excess plated metal brought from said adjusting part of the plate adhesion amount, and controlling the supplying amount of the plating metal at the plate treating parts in accordance with said measured value, and measuring the plated thickness at the downflow side of the line than the adjusting part of the plate adhesion amount, and controlling the film thickness at the adjusting part of the plate adhesion amount in accordance with said measured value.

33. A method as claimed in claim 1, characterized by adjusting the plate adhesion amount after having formed the plated film, detecting an end of a drop part of the excess plated metal brought from said adjusting part of the plate adhesion amount at the upflow side of the line than the adjusting part of the plate adhesion amount, and controlling the supplying amount of the plating metal at the plate treating parts in accordance with said detection, measuring the plated thickness at the downflow side of the line than the adjusting part of the plate adhesion amount, and controlling the film thickness at the adjusting part of the plate adhesion amount in accordance with said measured value.

34. A method as claimed claim 1, characterized by using as the plating metal material a Zn-Fe alloy material of not more than 60 wt% Fe, thereby to form a plated film of Zn-Fe alloy of not more than 60 wt% Fe in the surface of a steel sheet as the metal sheet.

35. A method as claimed claim 2, characterized by using as the plating metal material a Zn-Fe alloy material of not more than 60 wt% Fe, thereby to form a plated film of Zn-Fe alloy of not more than 60 wt% Fe in the surface of a steel sheet as the metal sheet.

36. A method as claimed claim 1, characterized by using as the plating metal material a Zn-Ni alloy material of not more than 30 wt% Ni, thereby to form a plated film of Zn-Ni alloy of not more than 30 wt% Ni in the surface of a steel sheet as the metal sheet.

37. A method as claimed claim 2, characterized by using as the plating metal material a Zn-Ni alloy material of not more than 30 wt% Ni, thereby to form a plated film of Zn-Ni alloy of not more than 30 wt% Ni in the surface of a steel sheet as the metal sheet.

38. A method as claimed claim 1, characterized by using as the plating metal material a Zn-Mn alloy material of not more than 60 wt% Mn, thereby to form a plated film of Zn-Mn alloy of not more than 60 wt% Mn in the surface of a steel sheet as the metal sheet.

39. A method as claimed claim 2, characterized by using as the plating metal material a Zn-Mn alloy material of not more than 60 wt% Mn, thereby to form a plated film of Zn-Mn alloy of not more than 60 wt% Mn in the surface of a steel sheet as the metal sheet.

40. A method as claimed in claim 1, characterized by using as the plating metal material a plating metal material dispersed with coloring pigments, and grinding the plated film surface after the plated film has been solidified for producing a colored plated metal sheet.

41. A method as claimed in claim 2, characterized by using as the plating metal material a plating metal material dispersed with coloring pigments, and grinding the plated film surface after the plated film has been solidified for producing a colored plated metal sheet.

42. A method of continuously plating metal sheets, characterized by repeatedly practising the plate treating process as claimed in claim 1 in the metal sheets passing line while solidifying the plated film between the respective processes, thereby to form a multi-layered plated film composed of homegeneous or heterogeneous kinds of the plated metals on the metal sheet.

43. A method of continuously plating metal sheets, characterized by repeatedly practising the plate treating process as claimed in claim 2 in the metal sheets passing line while solidifying the plated film between the respective processes, thereby to form a multi-layered plated film composed of homegeneous or heterogeneous kinds of the plated metals on the metal sheet.

44. A method of continuously plating metal sheets, characterized by practising, by at least once, the plate treating process as claimed in claim 1 and another plate treating process while solidifying the plated film by a cooling means between the respective processes, thereby to form a multi-layered plated film composed of homegeneous or heterogeneous kinds of the plated metals on the metal sheet, said another plate treating process charging the plating metal material into the plating metal supply device having a dissolving device of the plating metal material, melting in succession a chip of the plating metal material by said dissolving device, and continuously adhering the molten plating metal as a plated film to the surface of the passing metal sheet.

45. A method of continuously plating metal sheets, characterized by practising at least once the plate treating process as claimed in claim 2 and another plate treating process while solidifying the plated film by a cooling means between the respective processes, thereby to form a multi-layered plated film composed of homegeneous or heterogeneous kinds of the plated metals on the metal sheet, said another plate treating process charging the plating metal material into the plating metal supply device having a dissolving device of the plating metal material, melting in succession a chip of the plating metal material by said dissolving device, and continuously adhering the molten plating metal as a plated film to the surface of the passing metal sheet.

Fig.1

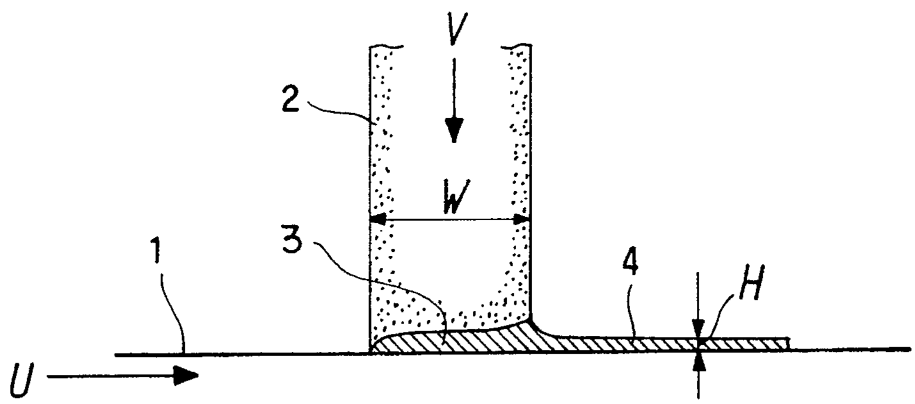


Fig.2

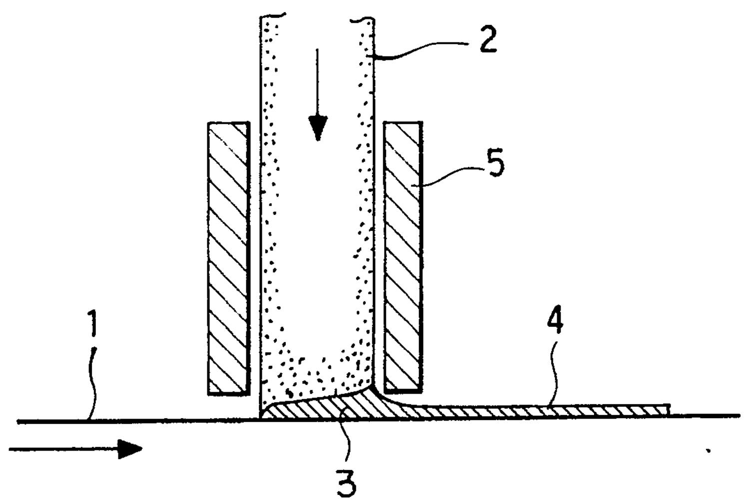


Fig.3

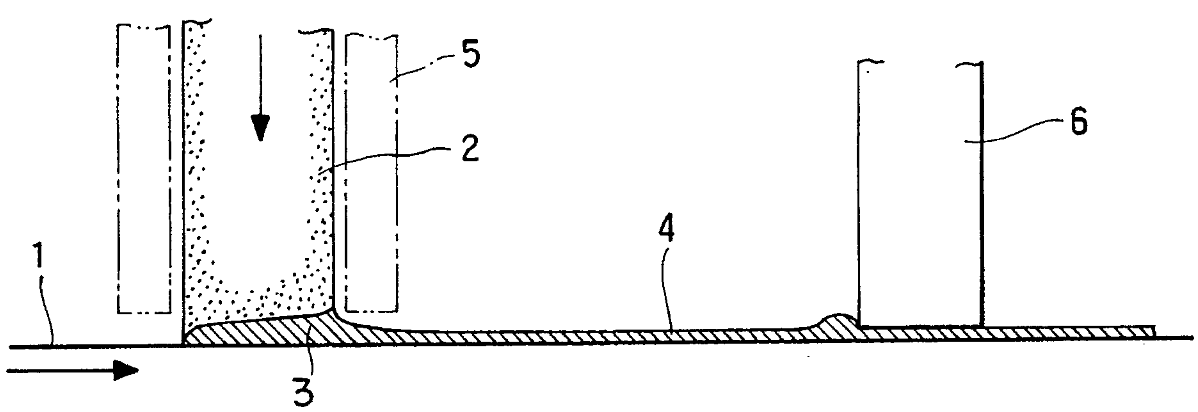


Fig.4

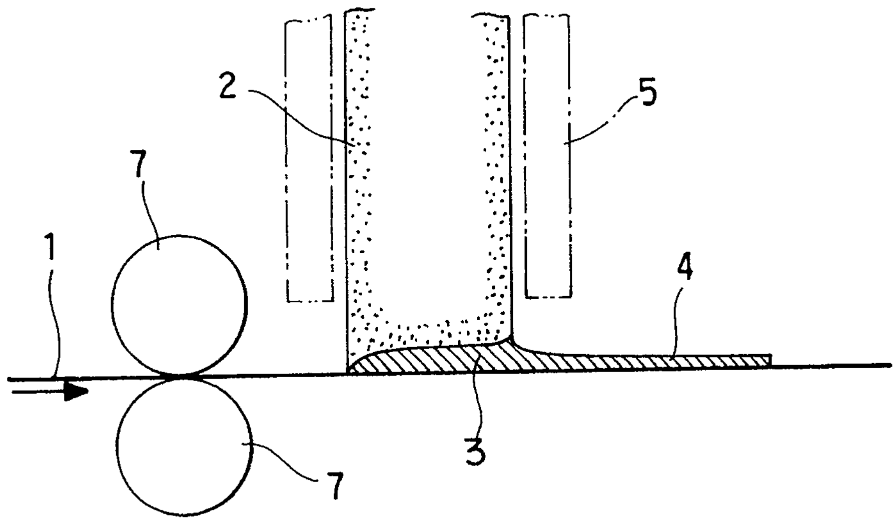


Fig.5

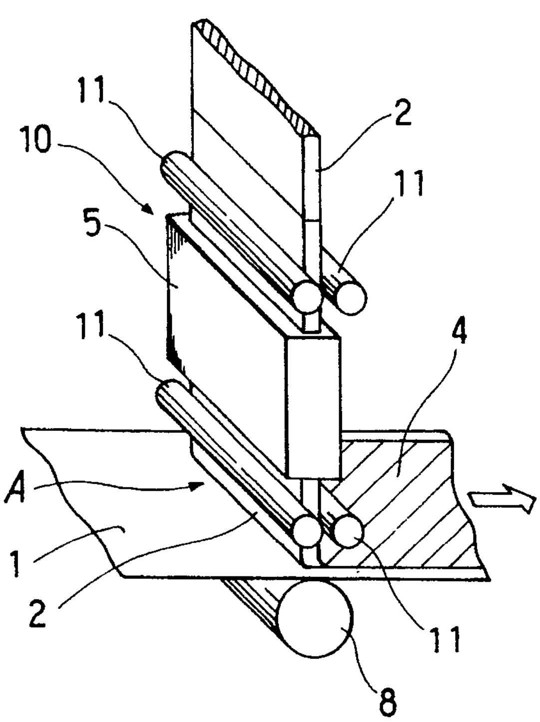


Fig.6

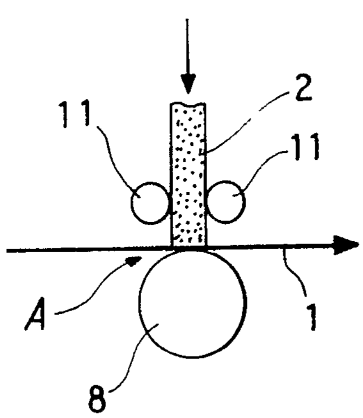


Fig.7

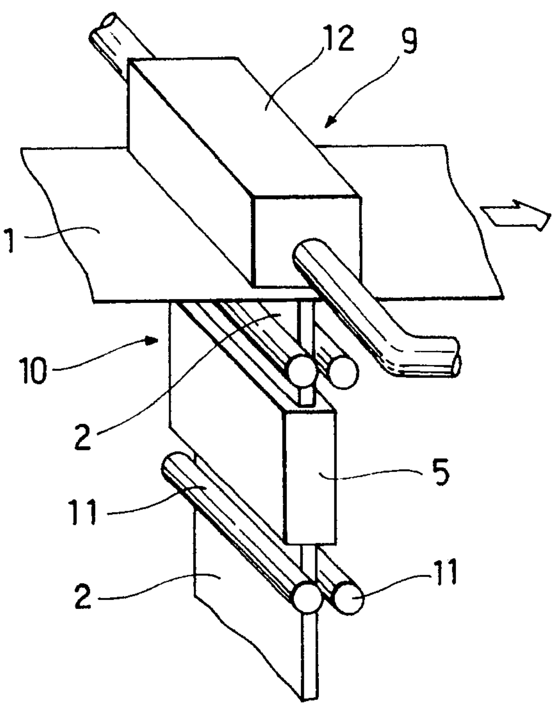


Fig.8

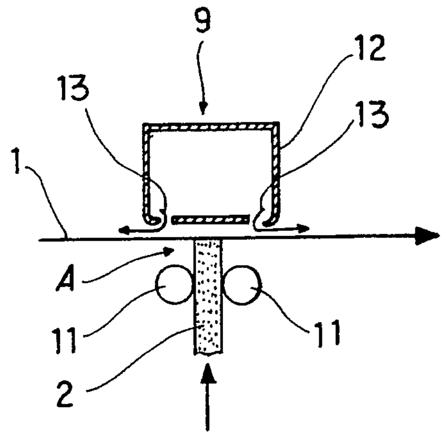


Fig.9

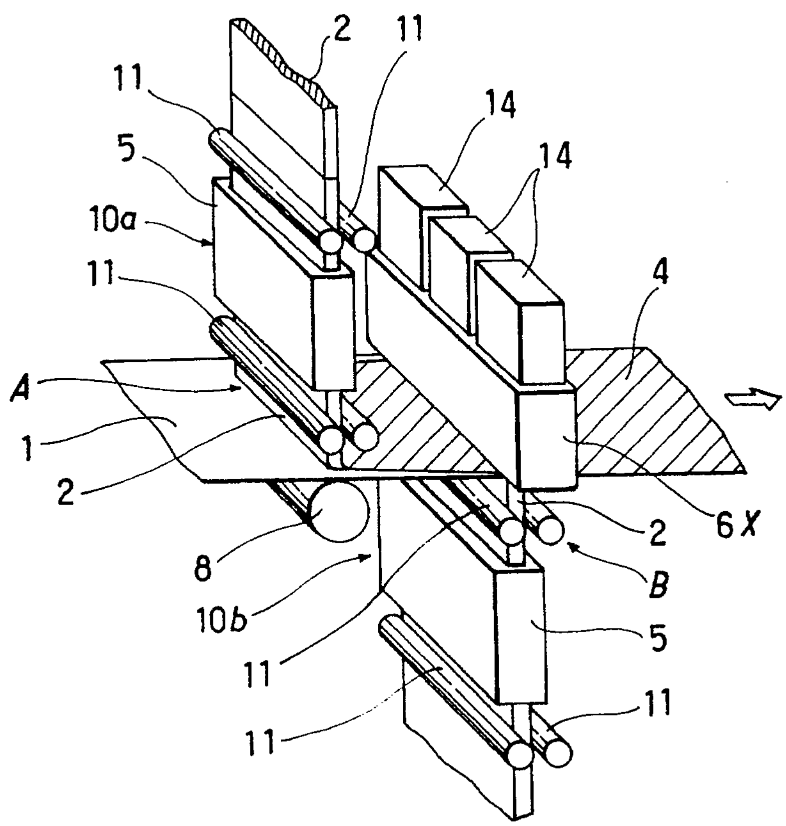


Fig.10

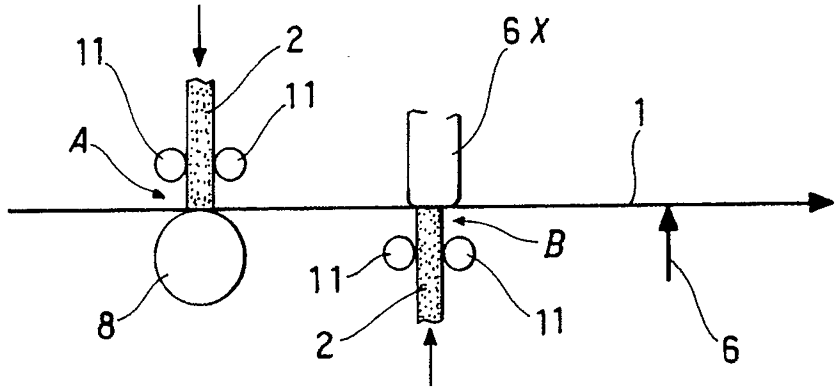


Fig.11

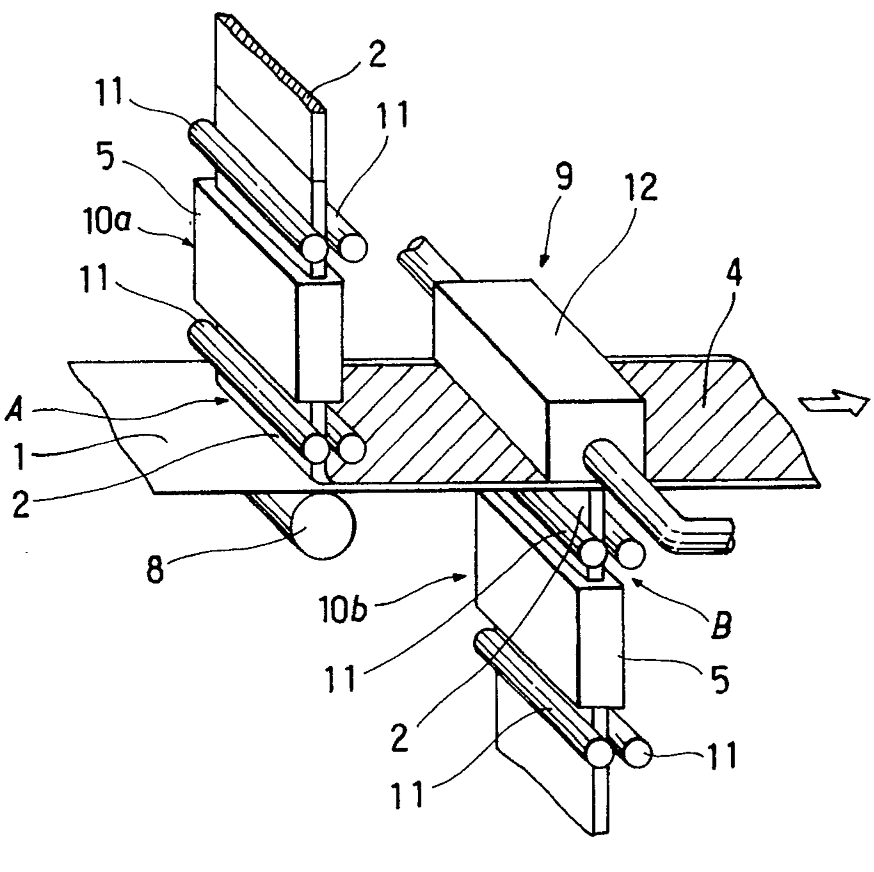


Fig.12

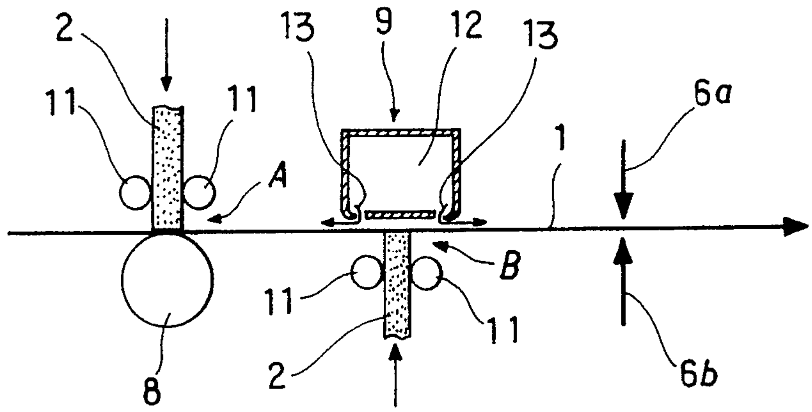

2
11
11
A
13
9
12
13
1
6a
B
11
11
2
8
6b

Fig.13

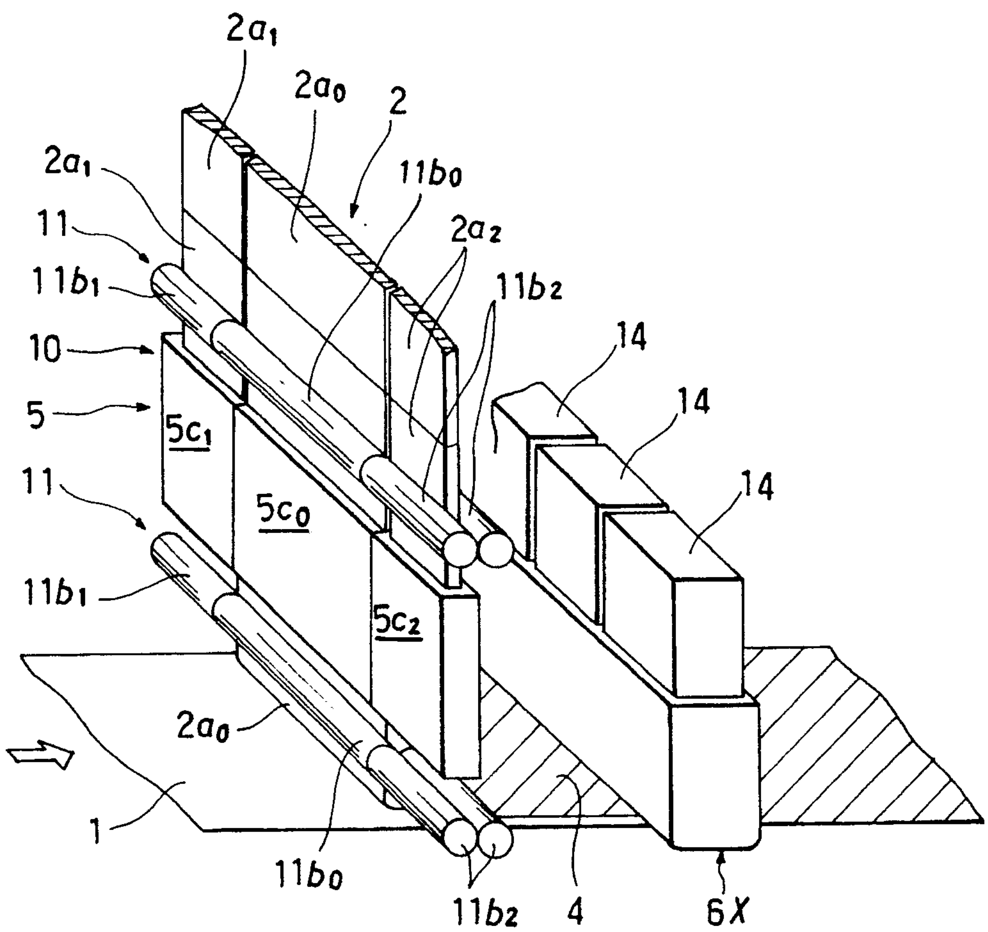

2a1
2a0
2
2a1
11b0
11
2a2
11b1
11b2
10
14
5
14
5c1
11
5c0
14
11b1
5c2
2a0
1
11b0
11b2
4
6X

Fig.14

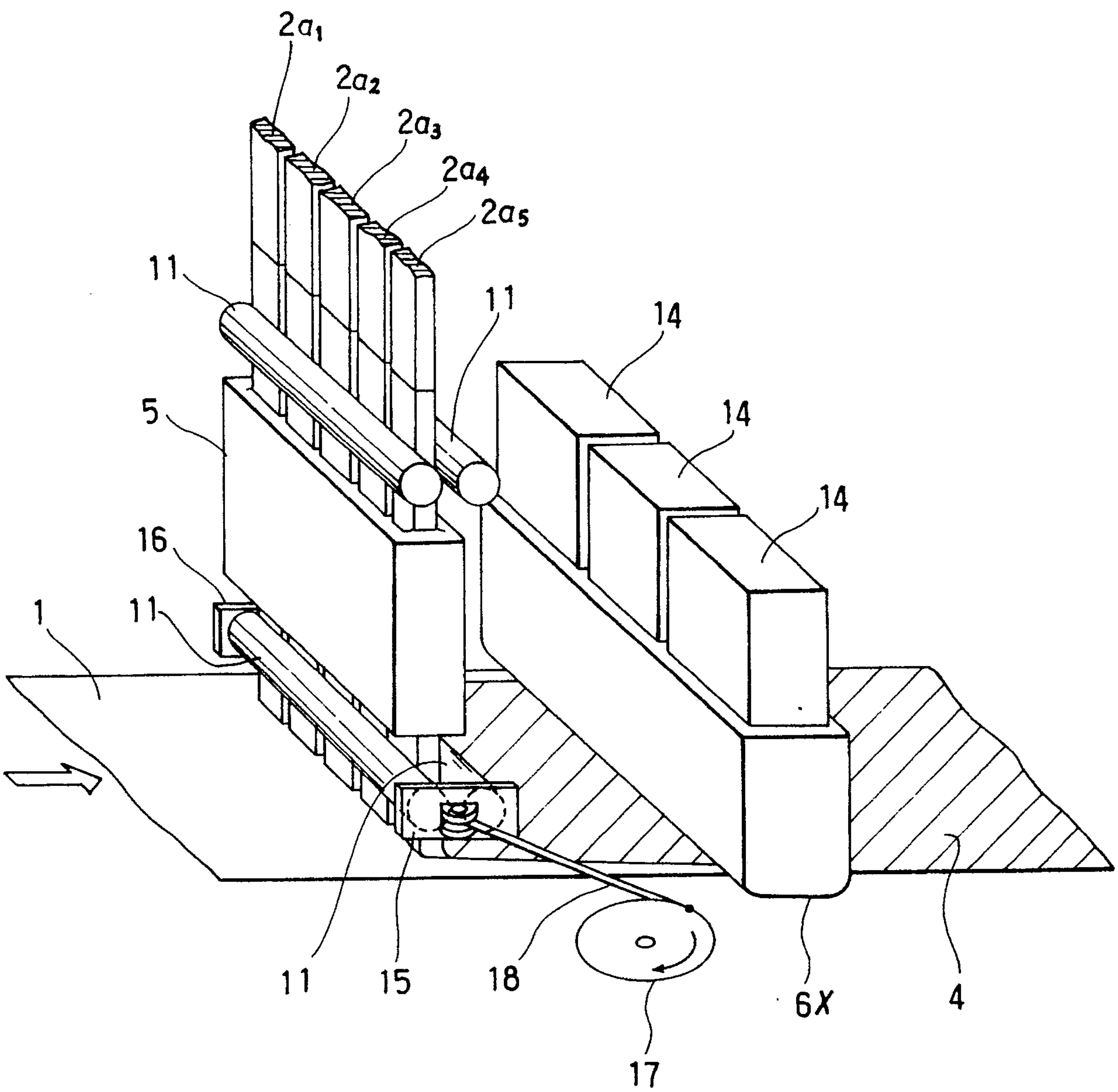


Fig.15

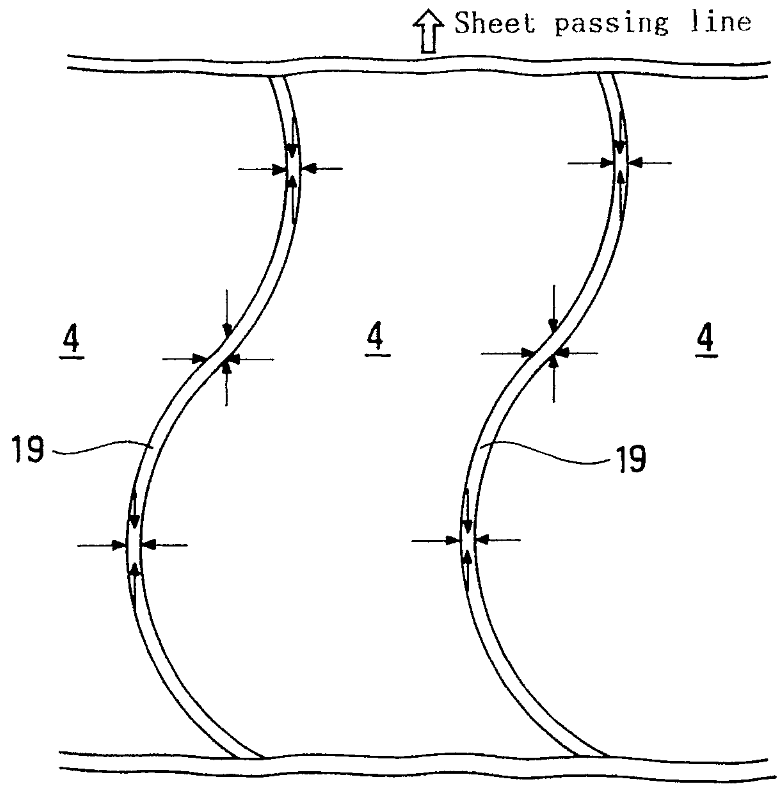

Sheet passing line
4
4
4
19
19

Fig.16

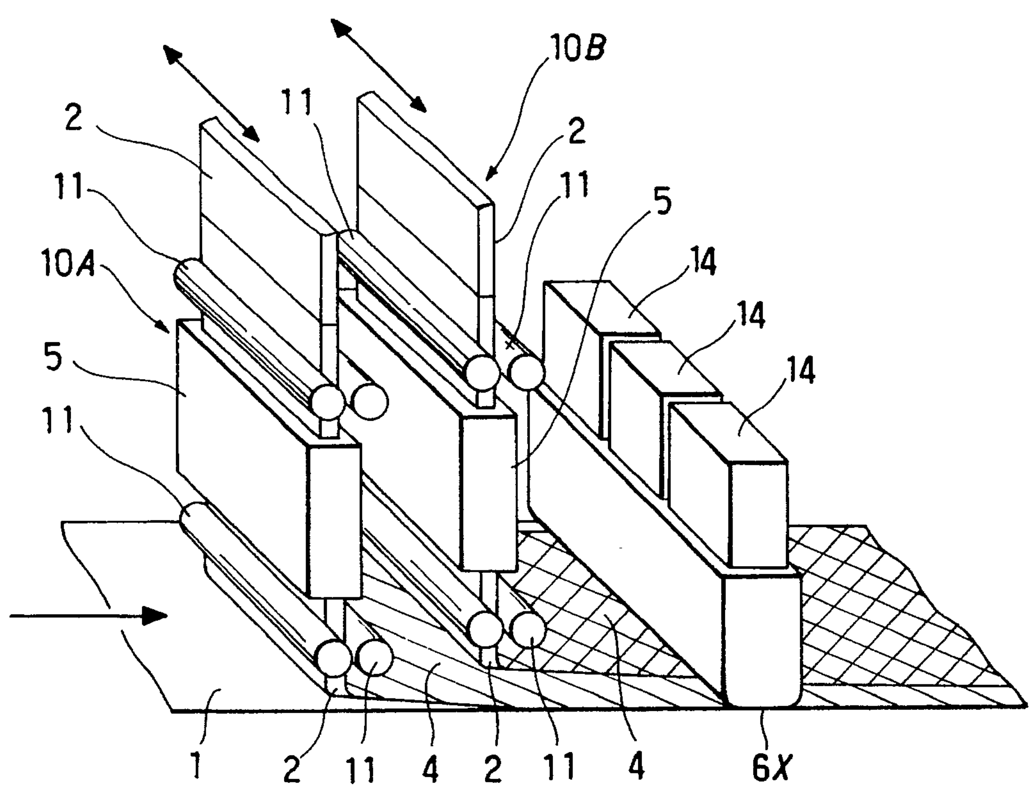

10B
2
11
2
11
11
5
10A
14
14
5
14
11
1
2
11
4
2
11
4
6X

Fig.17

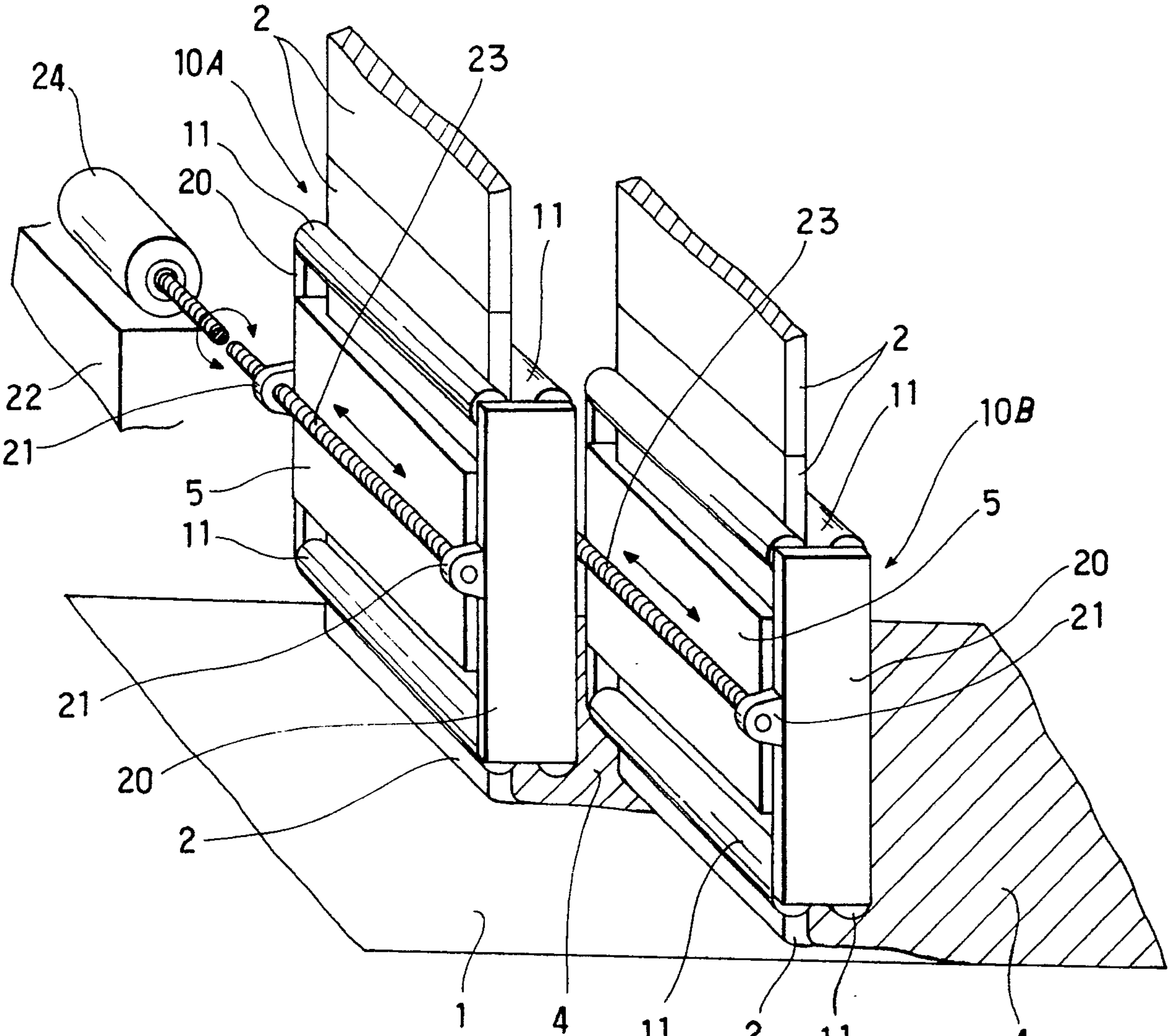


Fig.18

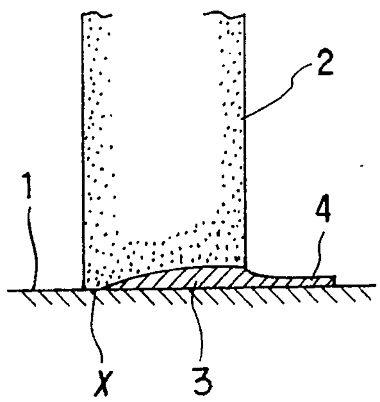


Fig.19

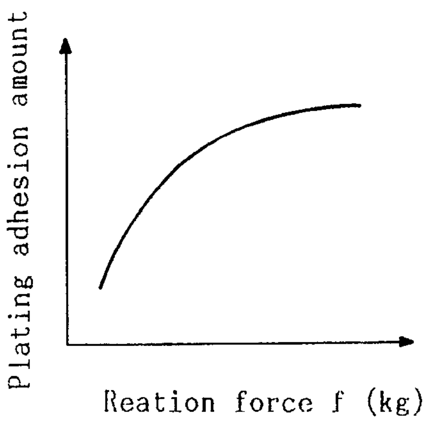


Fig.20

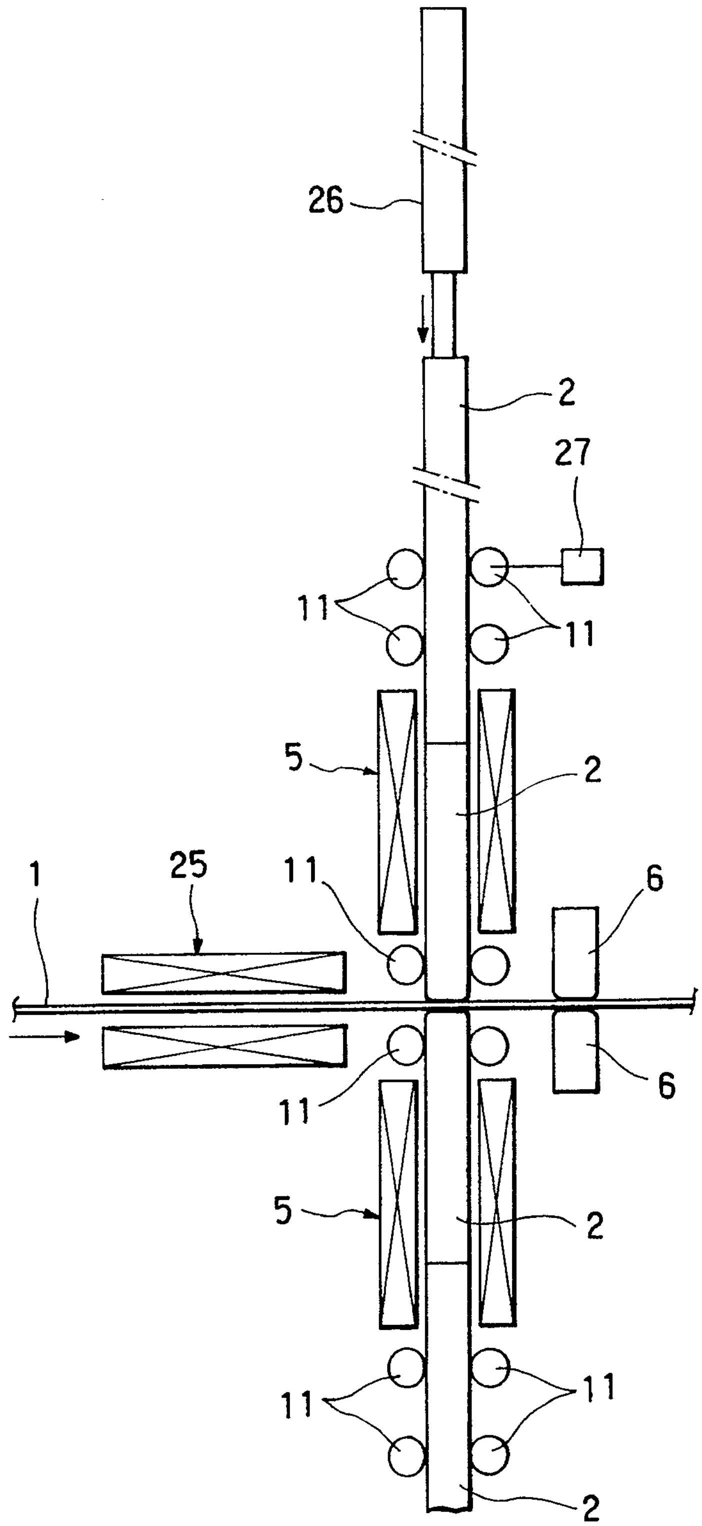


Fig.21

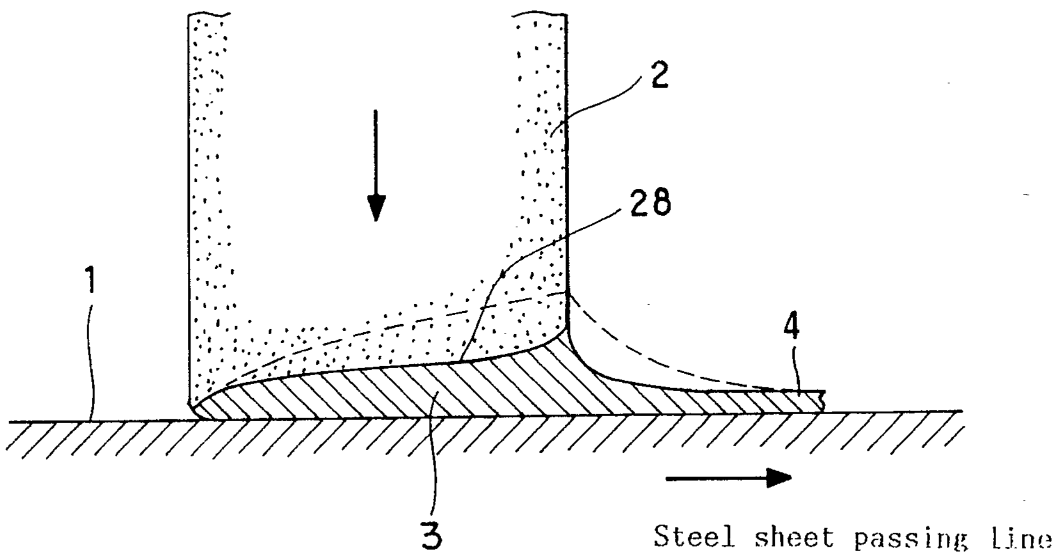


Fig.23

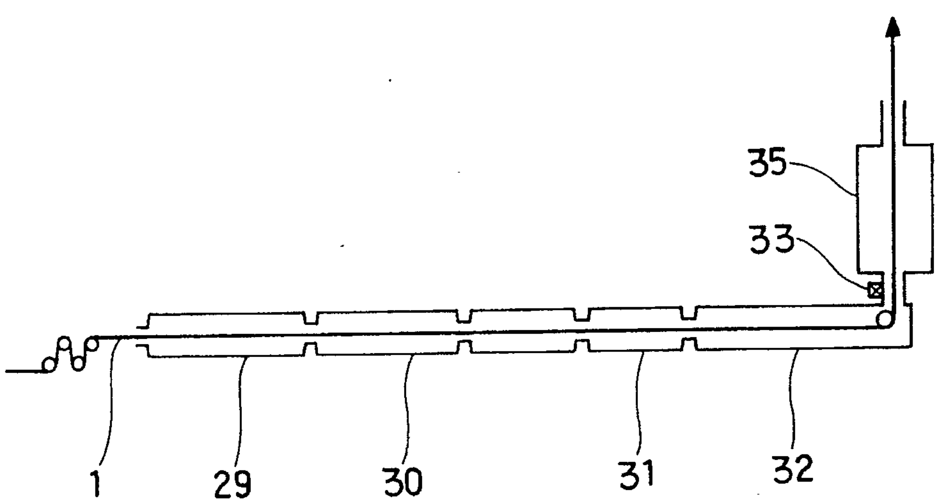


Fig.22

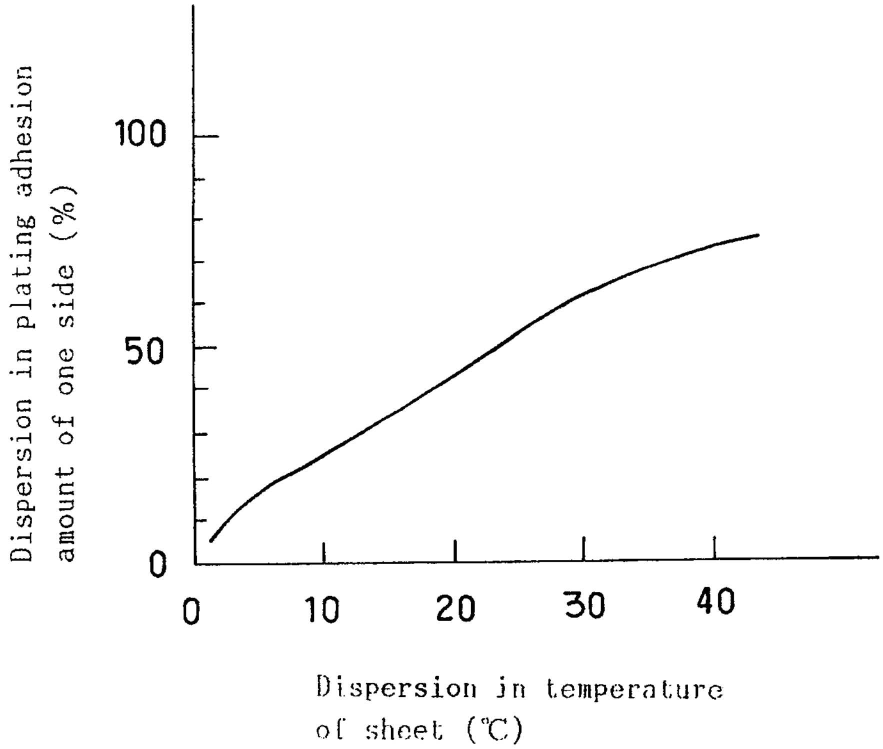

Dispersion in plating adhesion amount of one side (%)
100
50
0
0
10
20
30
40
Dispersion in temperature of sheet (℃)

Fig.24

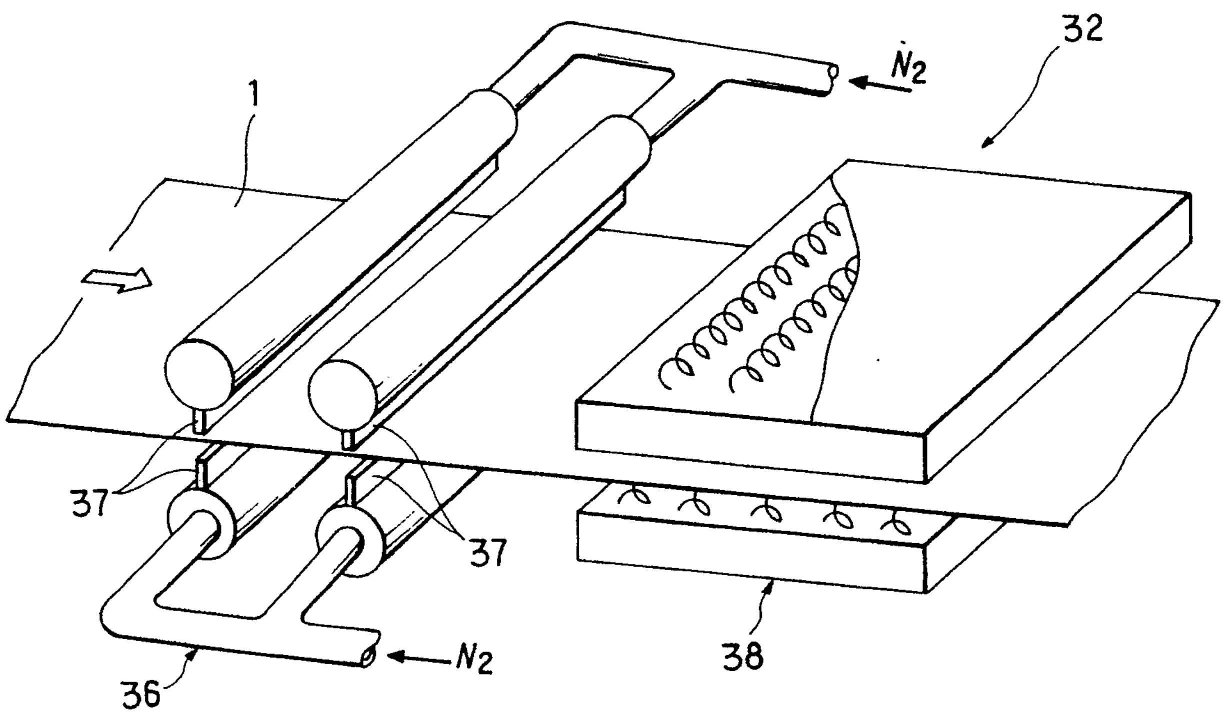

32
N_2
1
37
37
N_2
38
36

Fig.25a

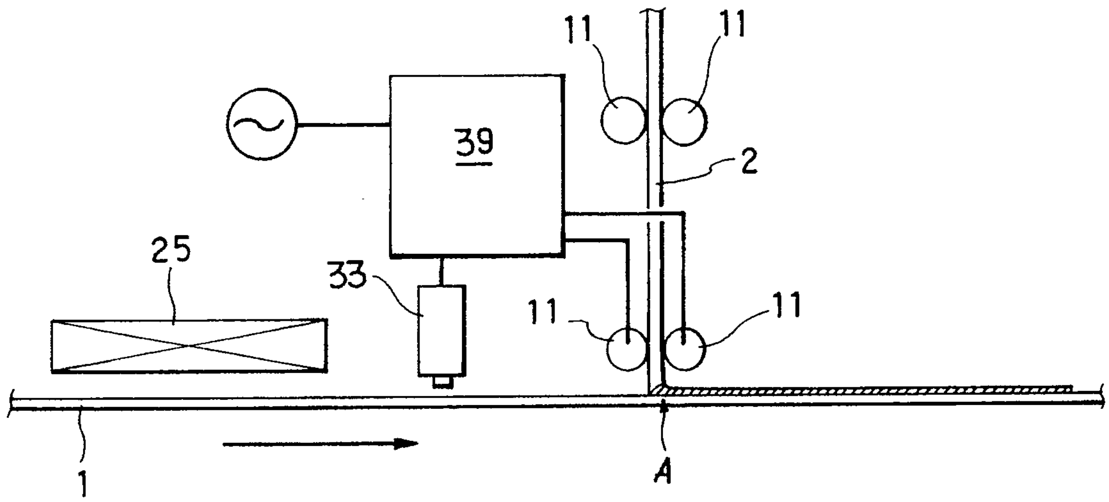


Fig.25b

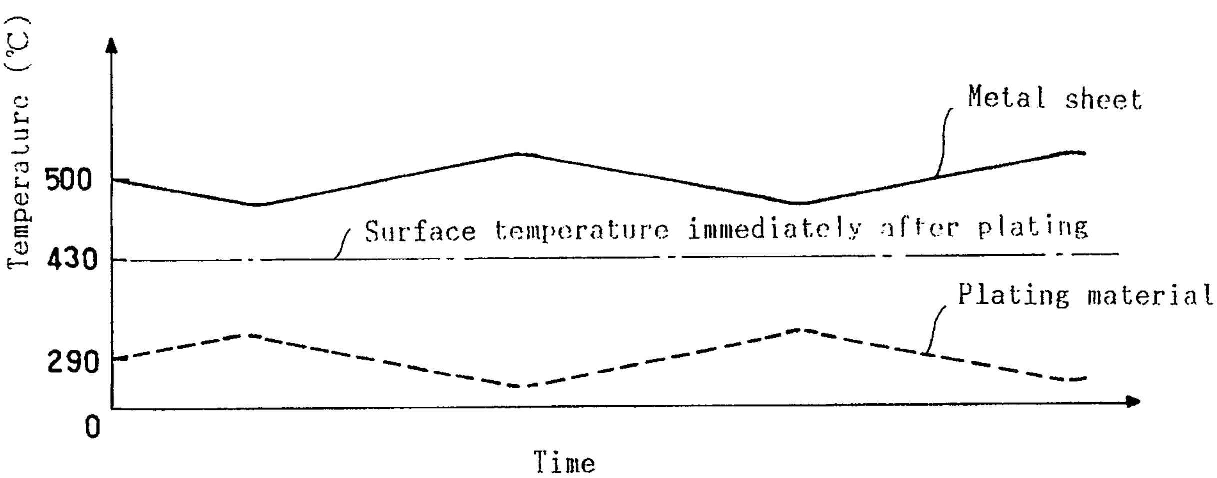


Fig.26

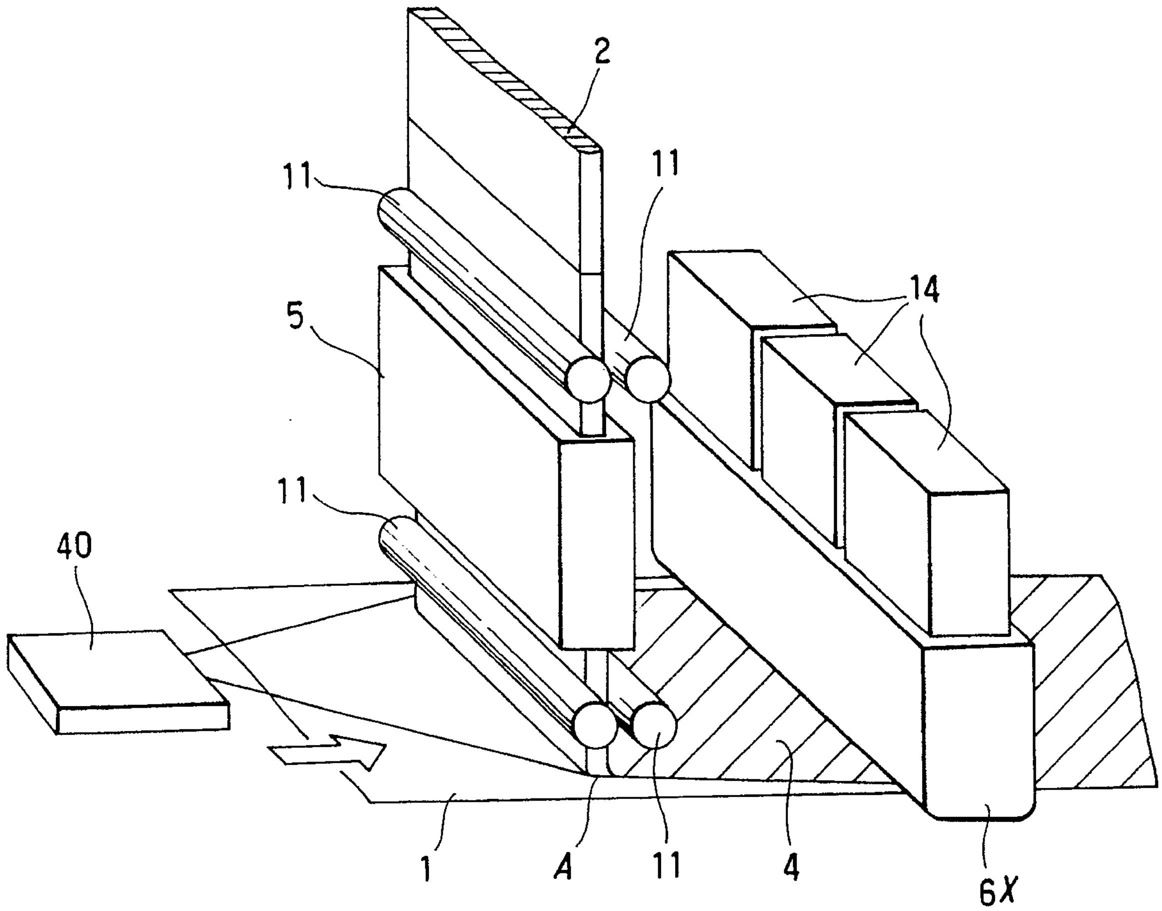

2
11
11
14
5
11
40
1
A
11
4
6X

Fig.27

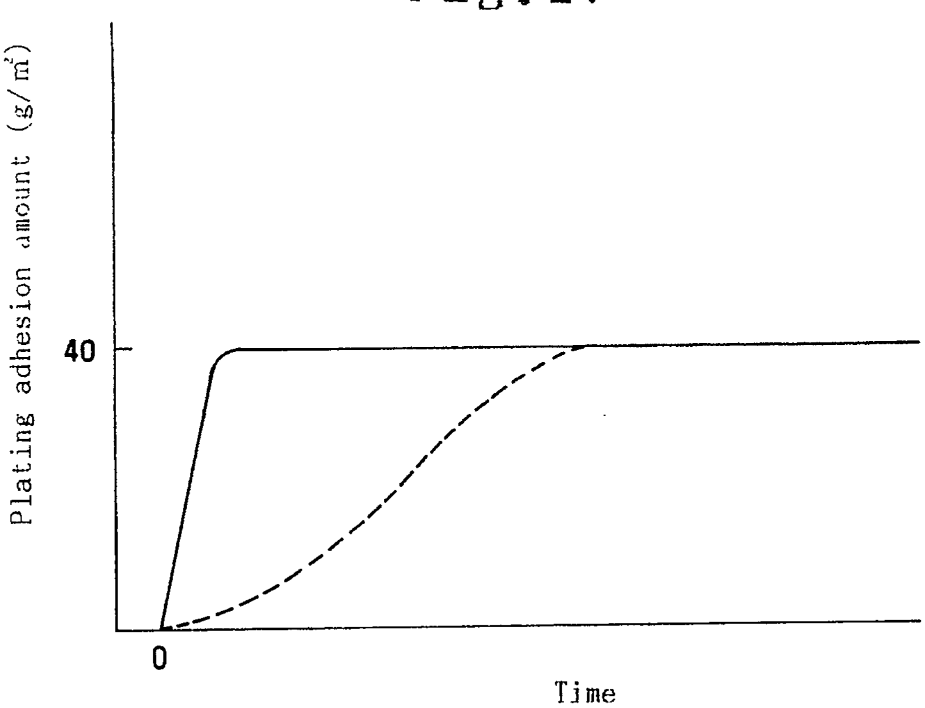

Plating adhesion amount (g/m²)
40
0
Time

Fig.32

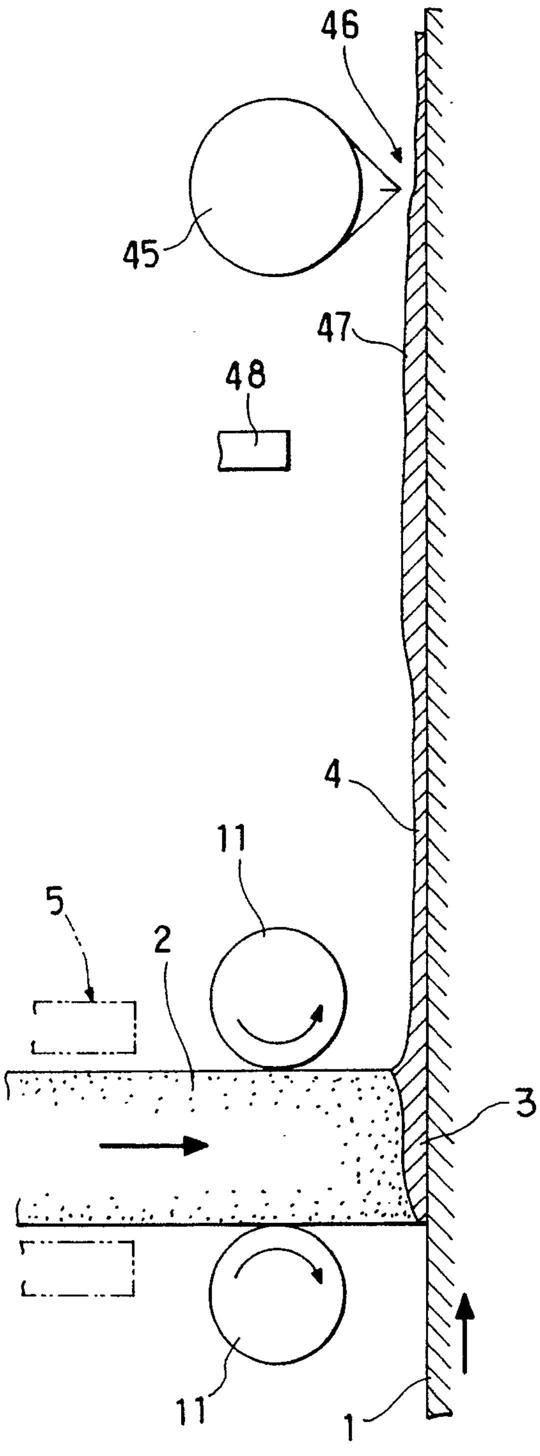


Fig.28

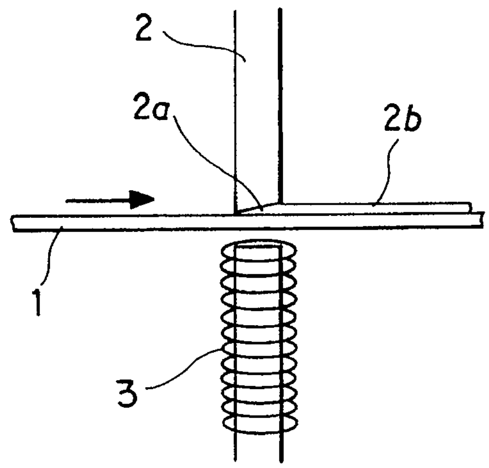


Fig.31

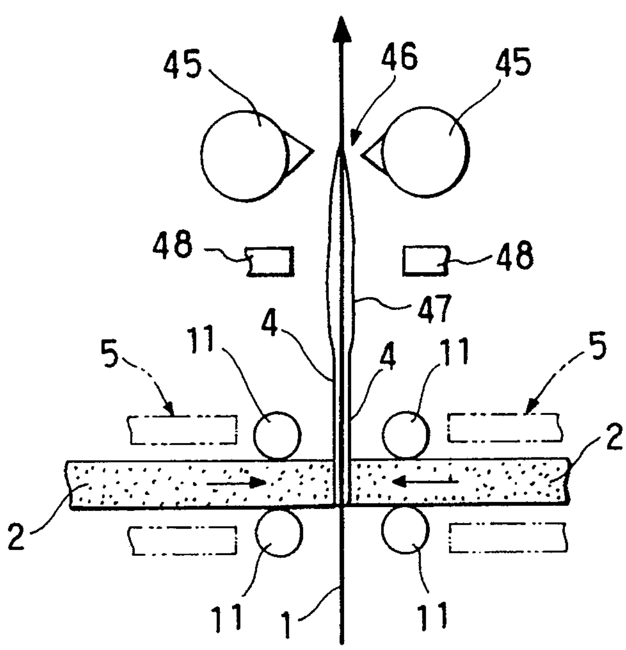


Fig.29

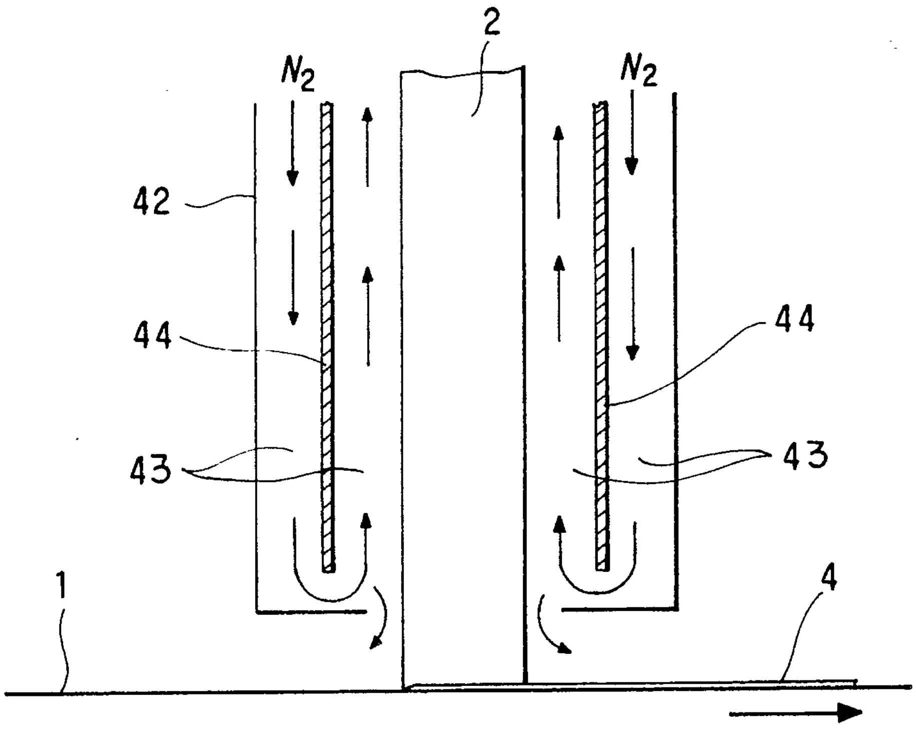


Fig.30

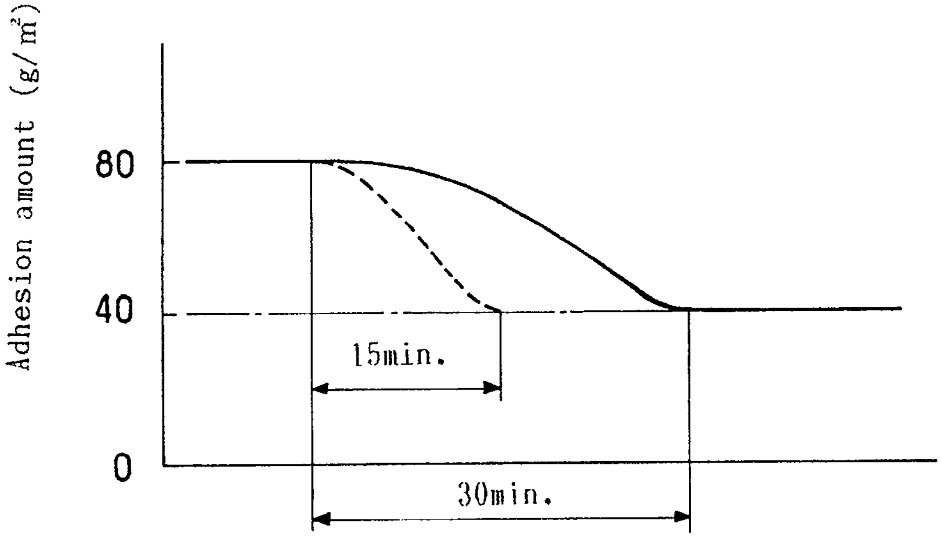


Fig.33

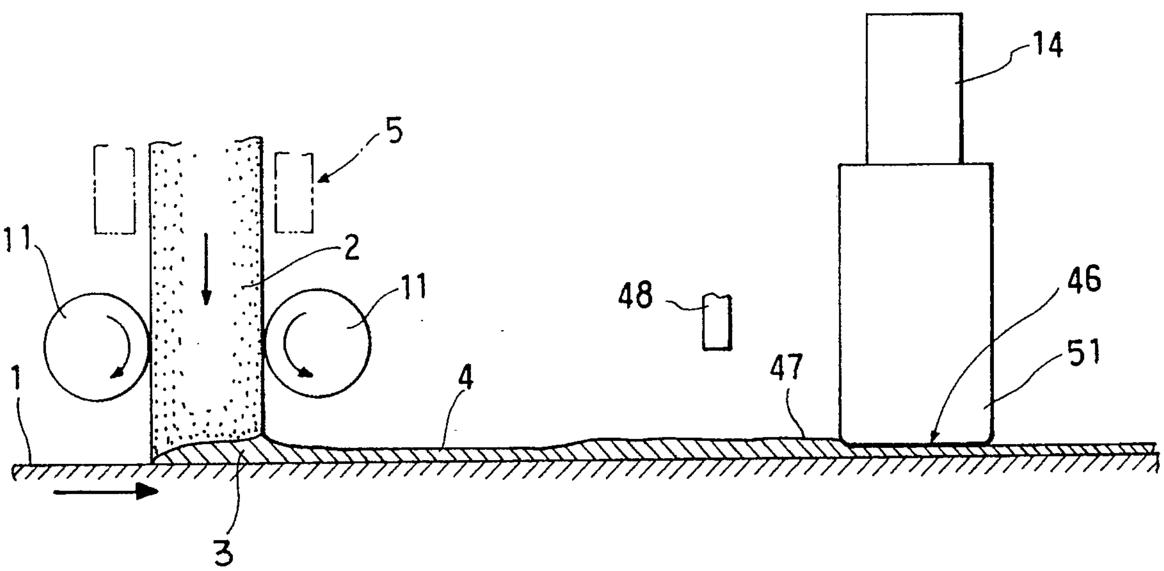


Fig.36

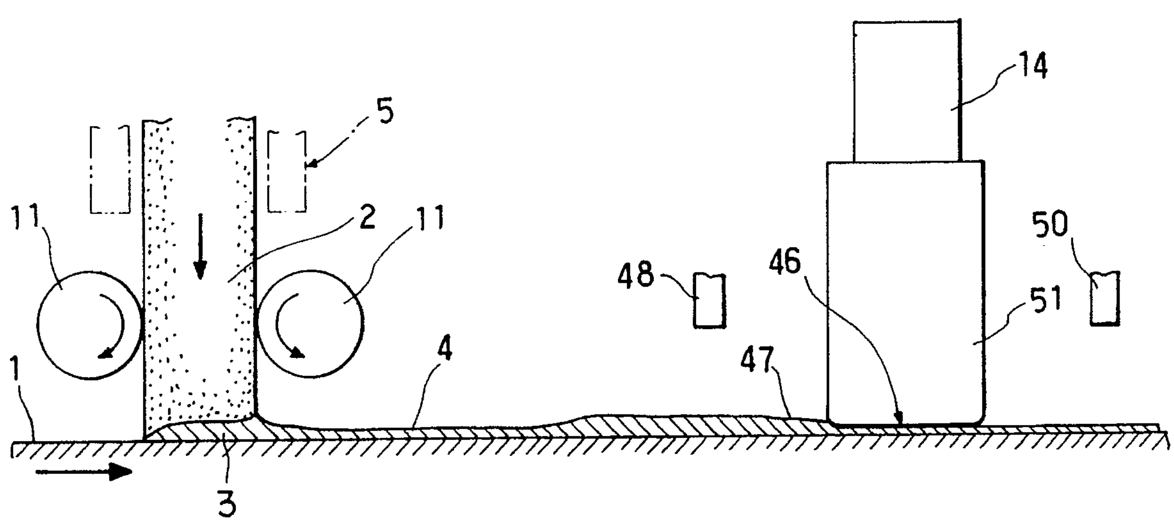


Fig.34

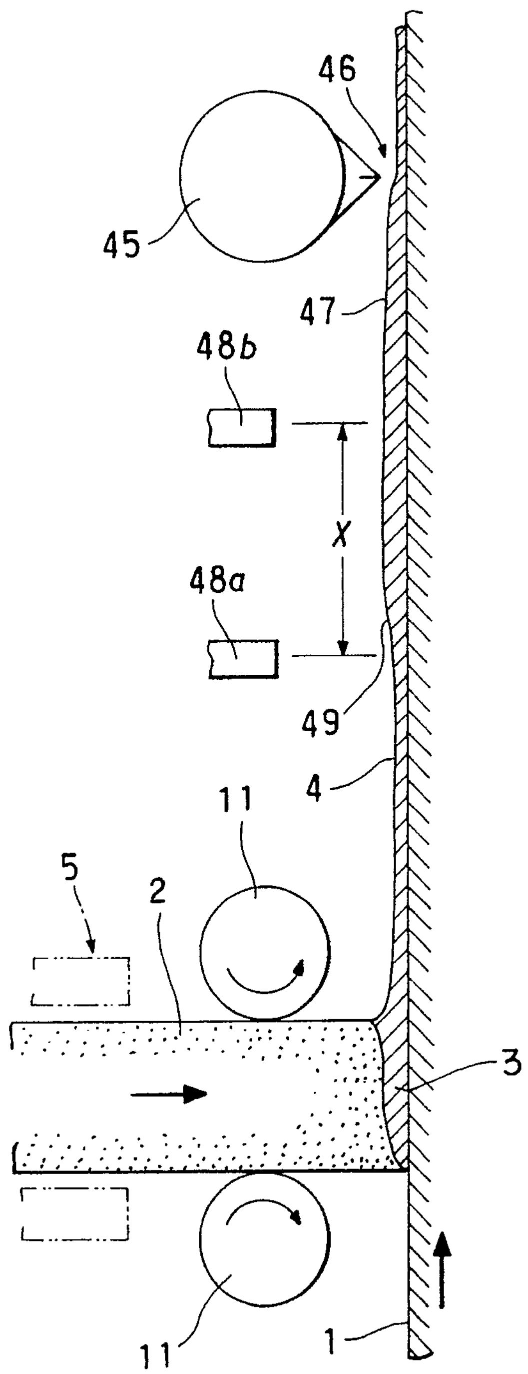


Fig.35

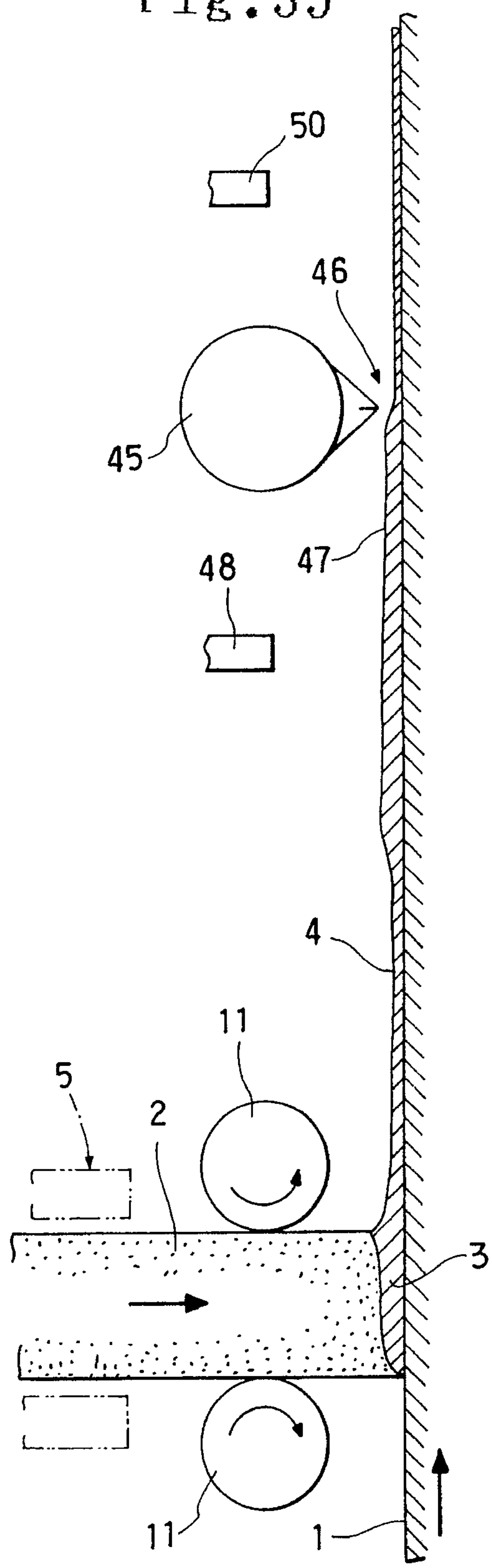


Fig.37

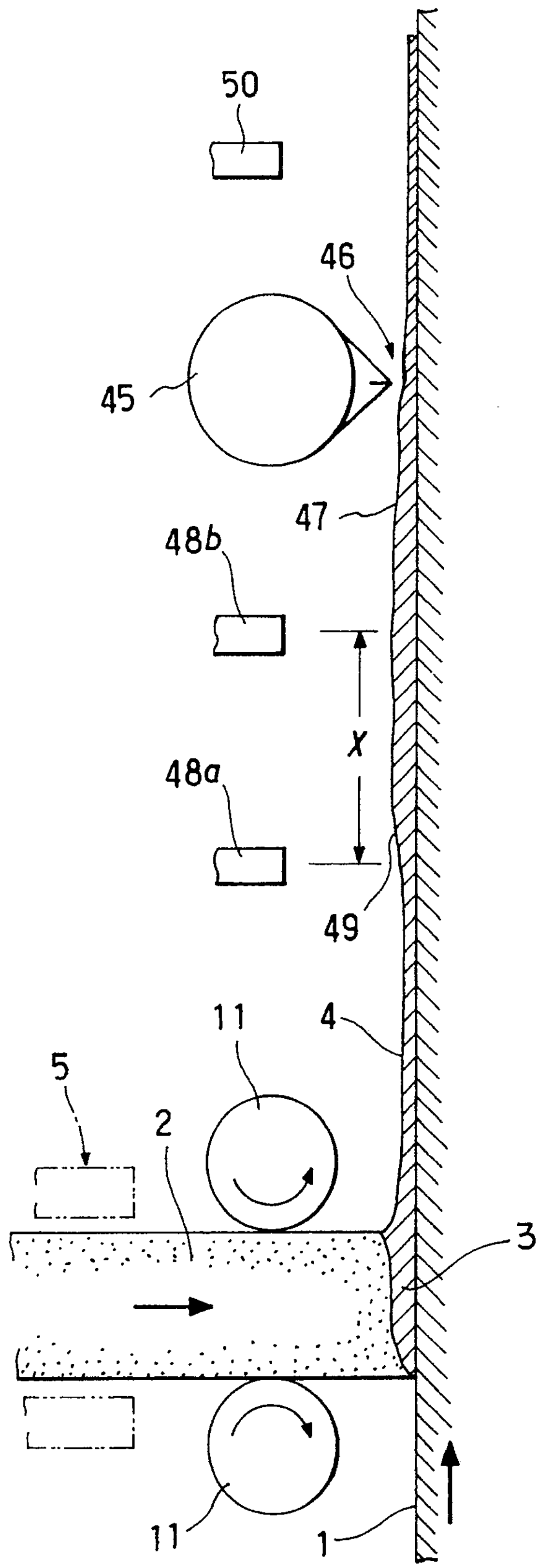


Fig.38

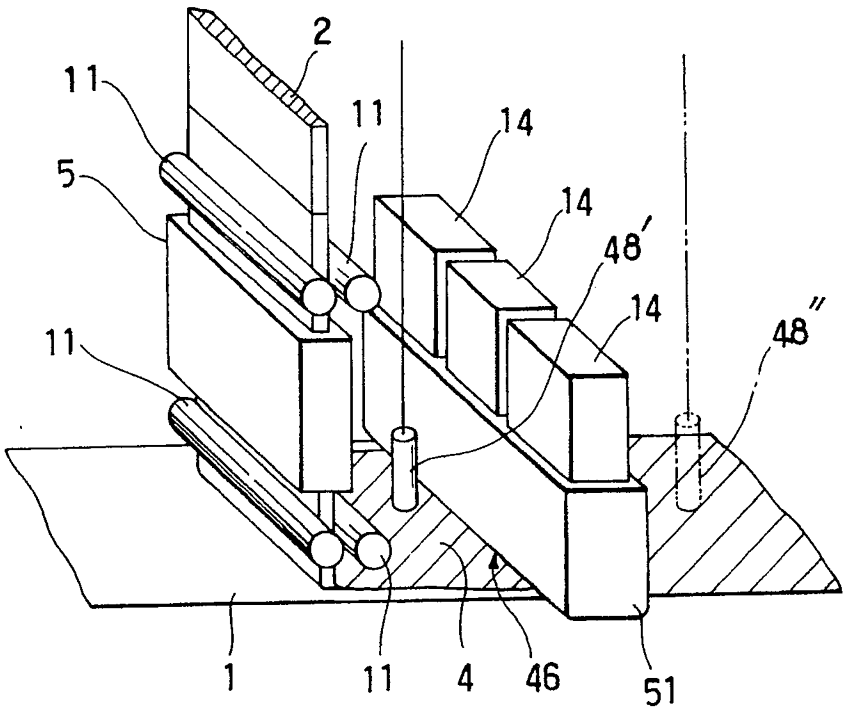


Fig.39

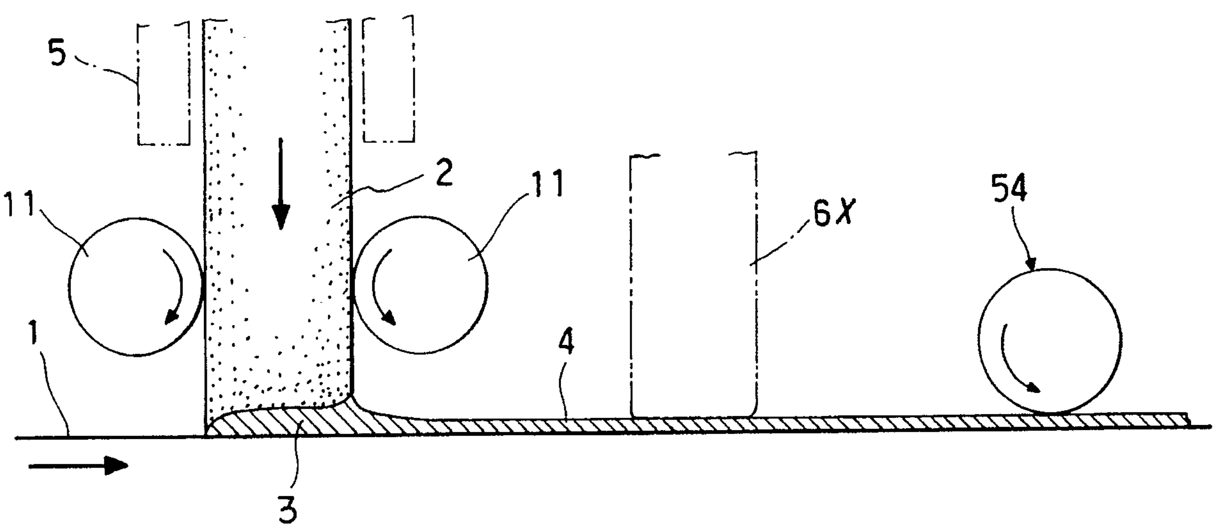


Fig.40

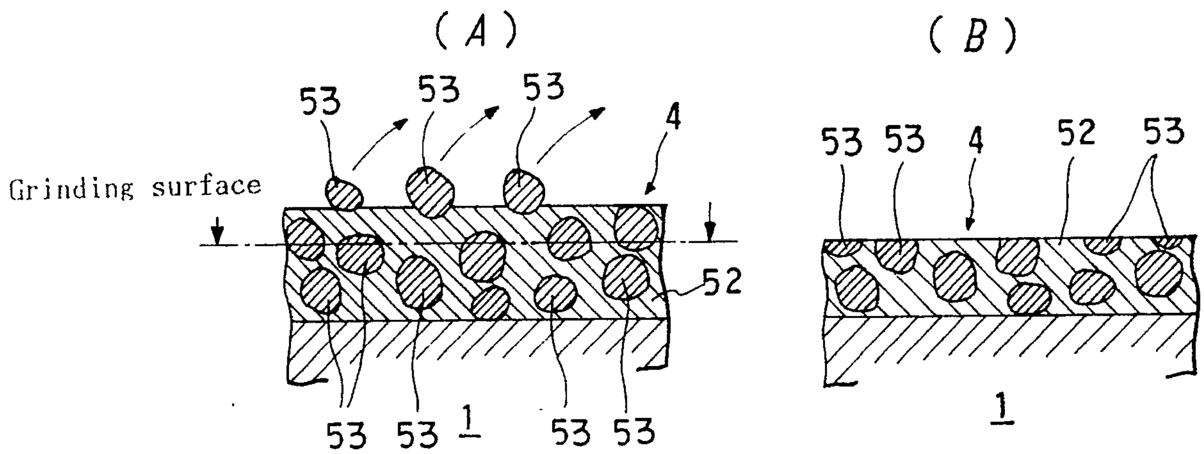


Fig.41

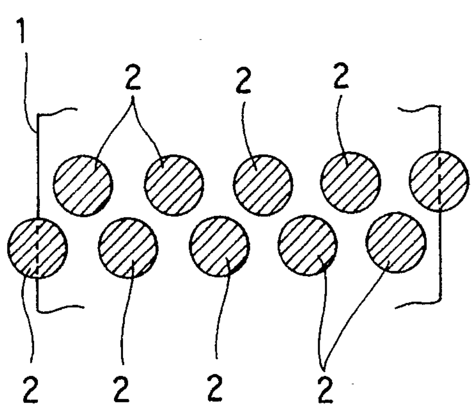


Fig.44

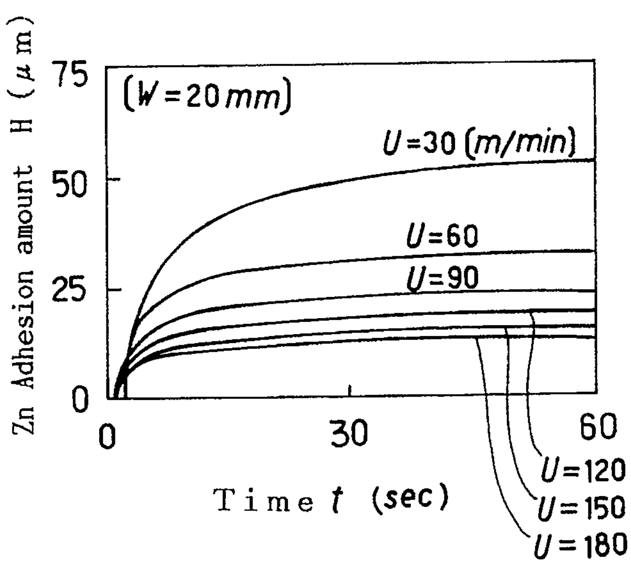


Fig.42

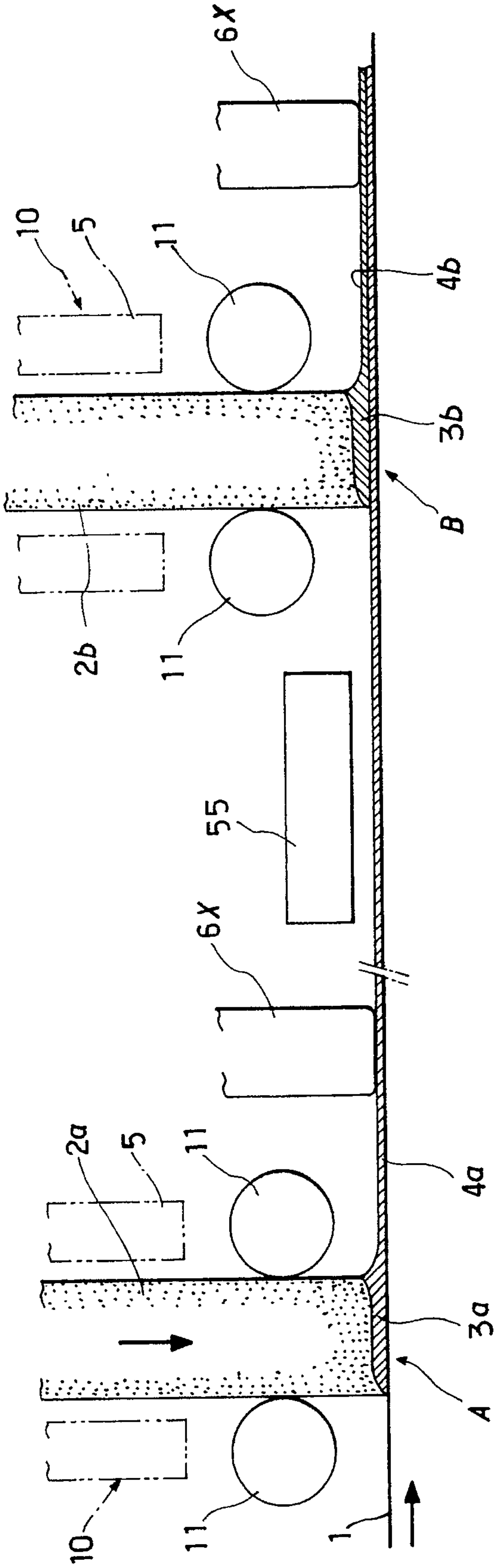
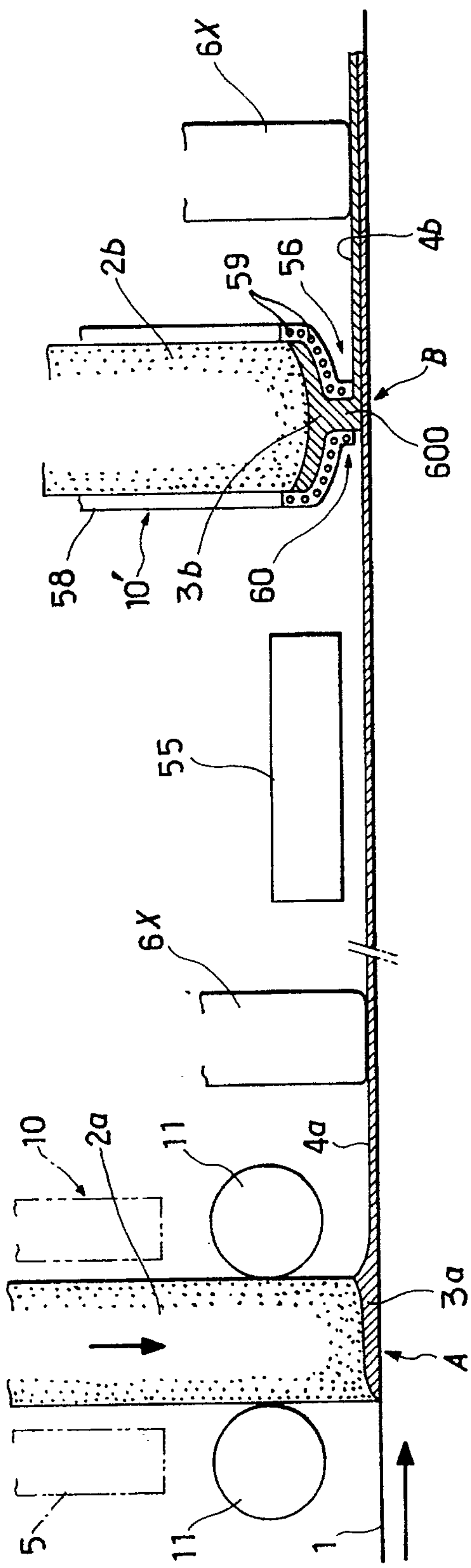

10
11
1
2a
5
3a
A
4a
6X
55
2b
3b
B
4b

Fig.43


5
11
1
10
2a
3a
A
4a
6X
55
58
10′
3b
60
600
2b
59
56
B
4b

INTERNATIONAL SEARCH REPORT

International Application No PCT/JP89/01094

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl[5] C23C2/00

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC	C23C2/00 - 2/40, C23C26/02, B05C5/04

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

Jitsuyo Shinan Koho	1926 - 1989
Kokai Jitsuyo Shinan Koho	1971 - 1989

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
Y	JP, B1, 46-29601 (New Nippon Electric Co., Ltd.), 28 August 1971 (28. 08. 71), Page 1, column 2, line 13 to page 2, column 3, line 5 and Figs. 1 to 2, (Family: none)	1 - 45

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
January 8, 1990 (08. 01. 90)	January 22, 1990 (22. 01. 90)
International Searching Authority	**Signature of Authorized Officer**
Japanese Patent Office	