

A METHOD OF SURFACE PROCESSING, A SURFACE PROCESS DEVICE, AND
A VTR DRUM, CYLINDER, PISTON, ROLLER OR ELECTROPHOTOGRAPHY
PHOTOSENSITIVE DRUM WITH THE SURFACE THEREOF PROCESSED

FIELD OF THE INVENTION

This invention relates to a surface process method for forming a hard, smooth and durable surface of a material, a surface process device, and a video tape recorder(referred to VTR hereinafter) drum, a cylinder, a piston, a roller or an electrophotography photosensitive drum with the surface thereof processed with the surface process method or with the surface process device.

BACKGROUND OF THE INVENTION

Conventionally, a surface layer is formed on various materials using substances giving desired properties to the materials, such that hardness, smoothness, wear resistance or other property of the materials is improved. For example, when the surface layer is formed of glass having hardness and smoothness on the material, the material is given raised hardness and smoothness.

In a proposed method of forming the surface layer of glass, glass powder is thermally sprayed on the surface of a metal.

However, following problem exists in such surface layer of glass. The surface layer is formed on the metal material different in quality from glass. Adhesion of glass to metal

is insufficient, even if the surface of the metal material is shot-blasted or buffed. Due to friction during long use, the interface between the surface layer and the metal material peels off or the surface layer itself peels off the material.

Since irregularities on the surface layer, resulting from the thermal spraying, stay as they are, the surface layer is insufficiently smooth.

In VTR, a tape always slides on the outer peripheral surface of a rotary or fixed drum. Therefore, the drum requires sufficient hardness and wear resistance to be durable against the sliding of the tape, and also requires surface smoothness so as to protect the tape from sliding friction. Conventionally, the drum is formed of aluminum alloy, and the outer peripheral surface of the drum is specularly finished by cutting and grinding. However, the outer peripheral surface is still insufficient in its hardness, smoothness and wear resistance. Cylinders and pistons in use for an air compressor, an air-conditioner refrigerant gas compressor or an engine also receive friction on their inner and outer peripheral surfaces, and require to have hardness and wear resistance to bear such friction. Sufficient smoothness is also required so as to reduce the quantity of energy consumed by the friction. Also, an electrophotography photosensitive drum receives friction with a brush and a printing sheet sliding on the outer peripheral surface thereof, and requires hardness and wear resistance to bear the friction. Sufficiently smoothness is also required

for the drum, such that the printing sheet and the brush are protected from friction with the drum.

SUMMARY OF THE INVENTION

Wherefore, an object of this invention is to provide a glass surface layer having sufficient adhesion to material and having surface smoothness, such that the hardness, smoothness and wear resistance of the material are enhanced.

To attain this and other objects, the invention provides a method of surface processing, in which a surface of workpiece is heated and melted, water glass is applied to the surface and immediately the surface is plastically deformed.

In another method according to the invention, water glass is first applied to the surface of workpiece, the surface is heated and melted, and immediately the surface is plastically deformed.

In further method according to the invention, the surface of workpiece is heated and melted, concurrently water glass is applied to the surface, and immediately the surface is plastically deformed.

Instead of water glass, water glass mixed with metal powder, ceramic powder or silicon dioxide powder can be used. As the metal powder, titanium powder is used, and as the ceramic powder, alumina powder is used.

In the invention the surface of the workpiece is plastically deformed by rolling or burnishing.

As aforementioned, immediately after the surface of

workpiece is thermally melted and water glass or water glass mixed with the aforementioned powder is applied to the surface, immediately after water glass or powder mixed water glass is applied to the surface and the surface is thermally melted, or immediately after the surface is thermally melted and concurrently water glass or powder mixed water glass is applied to the surface, plastic deformation is carried out.

During the plastic deformation, pressure is given such that water glass or powder mixed water glass is mingled or entangled at the interface with the melted or half-melted surface of the workpiece. Remarkably firmly adhered structure is formed between the workpiece and the water glass or powder mixed water glass.

The plastic deformation smoothens the surface of water glass or powder mixed water glass. Concurrently, heat of melted or half-melted part of the surface changes water glass into usual hard glass. Through cooling, the glass layer is formed on the surface of the workpiece. Consequently, the surface of the workpiece is given improved hardness, smoothness and durability.

By using the water glass with metal powder, ceramic powder or silicon dioxide powder added thereto, hardness, wear resistance, smoothness or other quality of the glass surface layer can be enhanced. As metal powder, titanium powder or other is available, as ceramic powder, alumina powder, titanium carbide, titanium nitride or other is available, and the silicon dioxide powder is available. As

powder, ultramicro particles with a particle diameter of 50 to 300 angstrom are desirable for making better the quality of and improving the smoothness of the surface layer. In the powder mixed water glass, 8 to 10% by weight of titanium or other metal powder is desirably mixed, 15 to 30% by weight of alumina, titanium carbide, titanium nitride or other ceramic powder is desirably mixed, or 15 to 20% by weight of silica or silicate dioxide powder is desirably mixed. Especially, titanium powder advantageously enhances hardness, smoothness, wear resistance, heat resistance and rust prevention, alumina powder enhances hardness and wear resistance, titanium carbide, titanium nitride enhances hardness, and silica enhances heat resistance of the surface layer.

Plastic deformation is executed by rolling or burnishing. During burnishing, the workpiece is compressed with a burnishing roller or a mandrel.

The invention also provides a surface process device provided with a heater for heating a part of the surface of a workpiece, an applicator provided adjacent to the heater for applying the powder mixed water glass on the heated part, and a plastic deforming processor provided adjacent to the applicator for plastically deforming the part applied with powder mixed water glass thereon by the applicator.

According to the invention, the heater combined with the applicator is composed of plasma discharge electrodes having a supply passage for guiding water glass toward the tip thereof. Plasma discharge is carried out in a gas or a mixed

gas, such gas being selected from N_2 , H_2 , Ar and He.

The invention further provides a VTR drum, a piston, a roller or an electrophotography photosensitive drum with the outer peripheral surface thereof processed in the aforementioned surface process method. Also, the invention provides a cylinder with the inner peripheral surface thereof processed in the surface process method.

In the surface process device, as a plastic deforming processor, a roller, a burnishing roller or a mandrel is used. As a heater, a plasma discharger, an ion plating unit, a laser radiator, an electronic beam radiator or other is used. Since water glass or powder mixed water glass is liquid, a nozzle, a roller, a spray, a doctor blade or other applicator suitable for applying liquid substance is used. Especially, when the roller is used as the plastic deforming processor, the same roller can be used also for applying water glass or powder mixed water glass. With the roller, the surface of workpiece can be finished with high precision. The use of roller especially strengthens metal material.

For the heater, when a plasma discharger or an ion plating unit is used, simply by directing the electrode incorporated in the heater to an electrically conductive workpiece, the desired part of the workpiece can be heated or melted. When a laser radiator or an electronic beam radiator is used, simply by directing laser or electronic beam to any workpiece irrespective of its conductivity, the desired part of the workpiece can be heated or melted.

The heater can also be combined with the applicator. Especially, when the heater and the applicator are composed of a plasma discharge electrode provided with the supply passage for guiding water glass or powder mixed water glass toward the tip thereof, another separate nozzle is required, thereby simplifying the structure of and reducing the size of the device for precise process.

Even if the VTR tape slides on the outer peripheral surface of the VTR drum, processed in the aforementioned surface process method, during long use, the glass surface layer is prevented from peeling off the VTR drum. The surface hardness and wear resistance of the drum can be maintained long, thereby resulting in high durability. Such highly durable drum can be used in good condition for a long time of period. Furthermore, since the VTR drum is provided with sufficient surface smoothness, wear on the VTR tape can also be reduced.

The cylinder having the inner peripheral surface processed, and the piston or the electrophotography photosensitive drum having the outer peripheral surface processed in the aforementioned surface process method can bear the sliding of another member on the peripheral surface thereof. The glass surface layer is prevented from peeling off the surface of the cylinder, the piston, the roller or the photosensitive drum, thereby maintaining surface hardness and wear resistance and providing high durability. Such highly durable cylinder, piston, roller and drum can be used

in good condition for a long time of period. They also have sufficient surface smoothness, thereby protecting the members sliding thereon from wear. Such cylinder and piston are used for the air compressor, the air-conditioner refrigerant gas compressor, the engine or other.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described, by way of example, with reference to the drawings, in which:

Fig. 1 is a schematic view showing a method of surface process of a VTR rotary drum embodying the invention;

Figs. 2A, 2B are cross-sectional views showing the forming of a glass layer on the outer peripheral surface of the VTR rotary drum;

Fig. 3 is a cross-sectional view of a surface process device embodying the invention;

Fig. 4 is a plan view of the surface process device;

Fig. 5 is an enlarged cross-sectional view of the main part of the surface process device;

Fig. 6 is a front view showing the periphery of an electrode nozzle or the surface process device;

Fig. 7 is a partial view showing the periphery of a roller of the surface process device;

Fig. 8 is a schematic view of a numerically controlled cutting machine or a machining center with the surface process device shown in Fig. 3 mounted thereon;

Fig. 9 is an enlarged cross-sectional view explaining

the main part of process being executed by the surface process device;

Fig. 10 is an end view of a laser radiator and a water glass applicator embodying the invention;

Fig. 11 is a left side view of the tip of the laser radiator and a water glass applicator; and

Fig. 12A is a schematic view of a head of modified surface process device embodying the invention, and Fig. 12B is a schematic view showing thermal application with an electrode combined with a function of discharge nozzle and plastic deformation with a mandrel.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIRST EMBODIMENT

As shown in Fig. 1, a VTR rotary drum 2, formed of aluminum or aluminum alloy, has a cylindrical periphery 4. For surface process, the VTR rotary drum 2 is firmly supported by a not-shown rotary device, by engaging a central shaft of the rotary device into an axial hole 6, such that the drum 2 is rotatable and its rotation axis is held steady.

An electrode 8, a nozzle 10 and a roller 12 are disposed in order at predetermined intervals on the upper part of a peripheral surface 4a of the drum 2. While the drum 2 is rotated, high voltage is supplied to the electrode 8 and plasma discharge starts on the peripheral surface 4a. Plasma discharge is carried out in, for example, Ar gas. Instead of Ar gas, He gas, H₂ gas, N₂ gas or the mixture of these gas can

be used. Part of the peripheral surface 4a is melted, thereby forming a melted layer 14. On the other hand, water glass is supplied via the nozzle 10 onto the melted layer 14, thereby forming a water glass layer 16. When the water glass layer 16 is rolled down with the roller 12, the melted and half-melted portions of the layer 14 and the water glass layer 16 are plastically deformed. During plastic deformation, the water glass 16 cools down the melted layer 14 and is concurrently heated and transformed to a glass layer 18.

About 8% by weight of ultramicro titanium powder having an average particle diameter of about 50 angstrom is mixed in water glass.

The entire peripheral surface 4a is, as aforementioned, heated, applied with water glass and rolled in series. The formed width of glass layer 18 is narrower than the width of the peripheral surface 4a. Therefore, the VTR rotary drum 2 is rotated and is concurrently moved in parallel with the rotation axis, such that the glass layer 18 is formed all over the peripheral surface 4a.

The aforementioned rotation and movement of the drum 2 is relative to the electrode 8, the nozzle 10 and the roller 12. Alternatively, they can be rotated and/or moved in parallel relative to one another or relative to the drum 2. For completely cooling of melted layer 14, cool water can be supplied via a cooling nozzle 20 to the roller 12 and/or to the glass layer 18.

The glass layer 18 is, as diagrammatically shown in Fig. 2A, formed on the peripheral surface 4a by heating the aforementioned water glass at high temperature, and forms a sufficiently hard surface layer. The surface 18a of the glass layer 18, compressed by the roller 12, is forced to form a surface having smoothness and precise dimensions, corresponding to precision in dimension of surface of the roller 12.

The melted or half-melted cylindrical periphery 4 of the drum 2 is brought in contact with water glass, transforming the powder mixed water glass into glass. The glass forms a layer mixed with aluminum alloy. In the mixed layer 22 glass and aluminum alloy are partly mixed with each other and are entangled with each other. The mixed layer 22 assists the glass layer 18 in firmly bonding to the cylindrical periphery 4. Even if glass powder is thermally sprayed on the surface of aluminum alloy, such mixed layer 22 fails to be formed. The glass layer 18 is prevented from peeling off the peripheral surface 4a during operation of the VTR rotary drum 2, different from the conventional art. The formed glass layer 18 is hard, wear-resistant, and is prevented from being worn by the VTR tape. The glass layer 18 is intrinsically non-porous. Further, the surface 18a of glass layer 18 is cooled and concurrently smoothened by the roller 12, different from as in just application of melted glass. The surface 18a has surface smoothness and is prevented from wearing the VTR tape.

Conventionally, when the peripheral surface 4a of the drum 2 is specularly finished of aluminum alloy, its Vickers hardness is 117Hv5, its friction coefficient μ_s is 0.123 and μ_k is 0.137, and frictional resistance force F_s is 24.54gf and F_k is 27.35gf. In the embodiment, when the glass layer 18 including titanium is formed on the peripheral surface 4a, its Vickers hardness is 160Hv5, its friction coefficient μ_s is 0.072 and μ_k is 0.059, and frictional resistance force F_s is 14.40gf and F_k is 11.72gf.

When the glass layer 18 is formed from water glass including 18% by weight of ultramicro alumina powder, its Vickers hardness is 164Hv5, its friction coefficient μ_s is 0.092 and μ_k is 0.084, and frictional resistance force F_s is 18.43gf and F_k is 16.72gf. When the glass layer 18 is formed from water glass including 40% by weight of ultramicro silica powder, its Vickers hardness is 145Hv5, its friction coefficient μ_s is 0.100 and μ_k is 0.076, and frictional resistance force F_s is 19.90gf and F_k is 15.14gf.

The glass layer 18 as shown in Fig. 2A is ground such that part 22a of the mixed layer 22 is exposed onto the surface 18a of the glass layer 18 as shown in Fig. 2B. The mixed layer 22 has sufficiently higher electric conductivity than the glass layer 18. Therefore, static electricity produced by friction between cylindrical periphery 4 and VTR tape is escaped from the VTR rotary drum 2, without being accumulated inside the drum 2. Since the glass layer 18 is formed remarkably thin, the surface condition can be from the

first as seen in Fig. 2B. In this case, grinding is hardly necessary.

When part 22a of the mixed layer 22 is exposed on the surface 18a, heat made by friction between the periphery 4 and VTR tape can be easily discharged. Because the mixed layer 22 has higher thermal conductivity than the glass layer 18. Therefore, temperatures are prevented from rising due to heat stored inside the drum 2. When alumina or silica is mixed in water glass, effectiveness similar to the aforementioned can be provided.

SECOND EMBODIMENT

As shown in Fig. 4, a surface process machine 101 is composed of a body frame 103, an electrode nozzle 105 for heating and applying water glass, a roller 107 for plastically deforming a surface and a guiding part 109.

The electrode nozzle 105 has a disc form as shown in Fig. 6. As shown in Fig. 5, an electrode 113 is disposed in a diametrical direction inside a disc board 111. Tip 113a of electrode 113 is exposed to the outside from the outer periphery of the disc board 111.

As shown in Fig. 3, opposite to the electrode 113, a nozzle 115 is disposed in a diametrical direction. In the body frame 103 a water glass passage 117 is passed through. Water glass mixed with powder in the same manner as the first embodiment is introduced from the guiding part 109 through the passage 117 toward the nozzle 115 and is discharged out of an opening 115a in the nozzle 115. In the water glass

passage 117, spacers 118a, 118b are provided for supporting a wire guide tube 127 in the middle of the passage 117.

As shown in Fig. 5, the electrode 113 is supported by an insulating spacer 119 inside the disc board 111. A closing plate 125 is in contact with one side of rear end 113b of the electrode 113. The opposite side of the rear end 113b is in contact with the wire guide tube 127, such that the electrode 113 is secured inside the disc board 111. A conducting wire 143 passing through the wire guide tube 127 is connected to the rear end 113b of the electrode 113. The closing plate 125 is opposed to the wire guide tube 127 and secured with screw onto the disc board 111.

The roller 107 is, as shown in Figs. 4 and 6, provided with four rollers 129, a roller frame 131 for rotatably supporting the rollers 129, an adjustment housing 133 and a locking nut 135. Each of the rollers 129 is rotatably secured onto every quarter of the periphery of the roller frame 131. A part of the roller 129 is, as shown in Fig. 7, inclined inwards by about 1.5 degrees relative to the axial direction or proceeding direction S of the body frame 103, such that the roller 129 is brought into contact with a workpiece by the part. Such inclination is provided for protecting the roller 129 from abrupt loading of the workpiece or for raising precision in processing the workpiece.

The roller frame 131 is a cylindrical member disposed at a predetermined position of the body frame 103. The movement

of the frame 131 is restricted in the axial direction by the adjustment housing 133 and the locking nut 135. The roller frame 131 is urged toward the adjustment housing 133 by a compression spring 137, disposed between an annular spacer 103b engaged with a stepped part 103a of the body frame 103 and a stepped part 131a of the roller frame 131. By adjusting the position of the locking nut 135 relative to the body frame 103, the position of the roller frame 131 can be adjusted via the adjustment housing 133.

The roller frame 131 can be rotatably urged toward the adjustment housing 133 by a bearing 133a disposed between the roller frame 131 and the adjustment housing 133. When the roller frame 131 is automatically rotated by a not-shown motor for surface processing, the rollers 129 attached to the tip of the roller frame 131 are rotated around a body mandrel 139 mounted on the tip of the body frame 103. In the embodiment, the components of the surface process machine 101 other than the guiding body 109a are rotated together in a unit.

Powder mixed water glass, refrigerant and high voltage are supplied by the guiding part 109 to the inside of the body frame 103: the water glass passage 117; a refrigerant passage 141; and the conducting wire 143 passed through the wire guide tube 127, respectively. The guiding part 109 is connected outside to a not-shown water glass source, a not-shown refrigerant source and a high-voltage source 145, respectively. As refrigerant, water is used in the

embodiment.

In use, as shown in Fig. 8, the aforementioned surface process machine 101 is supported by a tailstock 153 on a table 151 of a numerically controlled machine or a machining center. A workpiece 155 is rotatably supported by a chuck 157 and rotated at high speed by operating a motor 159. The movement of the tailstock 153 in directions X and Z, the rotation of a motor provided inside the tailstock 153 and the rotation of the motor 159 are restricted by a controller 161. Coincidentally, the quantity and the turning on/off of powder mixed water glass, refrigerant and electric power flowing into the water glass passage 117, the refrigerant passage 141 and the conducting wire 143, respectively, are also controlled by the controller 161. The workpiece 155 is formed of aluminum or aluminum alloy. As aforementioned, the guiding body 109a is held by the tailstock 153, and all the components other than the body 109a of the surface process machine 101 are rotated by the motor mounted inside the tailstock 153. As aforementioned, the surface process machine 101 can be adapted such that only the roller frame 131 is rotated.

When the cylindrical workpiece 155 is supported by the chuck 157, the surface processing is controlled as follows: at first, while the workpiece 155 is rotated at high speed, as shown in Fig. 9, the surface process machine 101 is inserted to inside 155a of the workpiece 155. Electrical power is transmitted from the high-voltage power source 145

through the conducting wire 143 to the electrode 113. Therefore, plasma is discharged between the tip 113a of electrode and the earthing workpiece 155. Part of workpiece 155 around the tip 113a is melted, thereby forming a melted part 201. Powder mixed water glass is supplied by the controller 161 to the nozzle 115. The opening 115a in the nozzle 115 is disposed behind the tip 113a of electrode toward the guiding part 109. A water glass layer 202 is formed with the nozzle 115 on the melted part 201 of the workpiece 155.

The water glass layer 202 is immediately rolled or burnished with the rollers 129. By rolling or burnishing, the water glass layer 202 is heated by the melted part 201 and is transformed into glass, thereby forming a highly precise and smooth surface or glass layer 203. Since the glass layer 203 is relatively hard, the hardness of surface of the workpiece 155 is increased. Further by plastic deformation, as aforementioned, since the mixed layer 204 is formed between the glass layer 203 and the workpiece 155, the glass layer 203 is firmly adhered to the workpiece 155. Since refrigerant or water is introduced from the refrigerant passage 141 to the surface of rollers 129, glass is prevented from sticking to the rollers 129.

In the embodiment, the rolling immediately follows the application of powder mixed water glass to the melted part 201 of aluminum alloy. Thus processed workpiece is provided with precise dimension and high performance. The

surface layer formed on the workpiece in the embodiment has hardness, wear resistance and high adhesion to the workpiece. Therefore, the workpiece is high in durability and smoothness, and can protect the members brought in contact with the workpiece from wear and tear.

By rotating only the roller frame 131 and forming the cross section of the body mandrel 139 polygonally, while the rollers 129 are rotated around the body mandrel 139 with being compressed by corner parts of the surface 139a of body mandrel, they can be cyclically displaced in the direction of workpiece 155. The metallic part of the workpiece 155 is peened by the rollers 129 and is hardened. The mixed layer 204 of glass and metal becomes complicated, thereby raising the durability of glass layer 203.

The workpiece 155, an electrical conducting wire, is heated and melted by displaceably discharging plasma. Even a low electrically conductive workpiece or a non-current carrying workpiece can be partly heated and melted by non-displacing plasma discharge, laser beam radiation or electronic beam radiation. For laser beam radiation, a laser oscillator can be provided inside the body frame 103, inside the disc board 111 or outside the surface process machine 101, such that laser beam is introduced toward the nozzle 115. For electronic beam radiation, the corresponding radiator is provided in the same manner.

THIRD EMBODIMENT

A laser radiator 171 shown in Fig. 10 is mounted on a

numerically controlled machine or a machining center for surface processing of workpiece 155. Laser beam is introduced to the part to be processed of the workpiece 155 by the laser radiator 171 from a not-shown external laser beam source. The part of the workpiece 155 is melted and concurrently powder mixed water glass is discharged to the melted part by the laser radiator 171.

As shown in Fig. 10, body 173 of laser radiator 171 almost has a shape of letter Z. The path of laser beam is provided with a guide tube 173a, a laser protective tube 173b, and a beam discharger 173c. Laser beam is introduced from the guide tube 173a through the laser protective tube 173b to the beam discharger 173c. After laser beam passes through a converging lens 173d, it is radiated through one passage of a nozzle 173e to the workpiece 155. Powder mixed water glass passage 175 connects with the other passage of nozzle 173e, as also shown in Fig. 11. Powder mixed water glass supplied from the outside is discharged from the nozzle 173e to the workpiece 155 behind the position of laser beam radiation, i.e. toward the side of the guide tube 173a.

By combining the roller 107 shown in Fig. 3 with the laser radiator 171, as shown in Fig. 9, a desired position of the workpiece 155 can be melted by laser beam and at the same time powder mixed water glass is sprayed onto the desired position. The application of laser beam and powder mixed water glass can be immediately followed by the rolling. With

this combination, the surface of a ceramic, glass or other non-current carrying workpiece can be processed.

FOURTH EMBODIMENT

As shown in Fig. 12A, three mandrels 305 are protruded into a central hole 303 of a cylindrical tool 301. A diamond tip member 307 is attached to the tip of each mandrel 305. The mandrel 305 is supported by a support 309 on the tool 301. The force applied to a workpiece 313 by the mandrels 305 is adjusted with respective screws 311. The support 309 is disposed in three of six recesses 315 provided on the tip of the tool 301. By fastening an annular lid member 317 onto the tip of the tool 301 with bolts, the support 109 is secured onto the tool 301.

An electrode nozzle 319 is secured to one of the recesses 315. As shown in Fig. 12B, a water glass supply passage 321 is provided in the center of the electrode nozzle 319.

In the embodiment the workpiece 313 is disposed in the central hole 303 of the tool 301. By bringing the mandrel tip members 307 into contact with the surface of the workpiece 313, the workpiece 313 is rotated in the direction of an arrow shown in Fig. 12A. High voltage is applied to the electrode nozzle 319 and at the same time powder mixed water glass 323 is supplied through the water glass supply passage 321. Plasma is discharged between the tip 319a of electrode nozzle 319 and the workpiece 313, thereby melting the surface of the workpiece 313 and forming a melted

part 313a. Powder mixed water glass 323 is applied from the water glass supply passage 321 onto the melted part 313a. While the workpiece 313 is rotated as aforementioned, the powder mixed water glass 323 is heated by the melted part 313a and is moved to the mandrel tip members 307. The surface of the workpiece 313 is compressed and burnished with the mandrel tip members 307.

Consequently, a glass layer 325, similar to the glass layer 18, is formed on the surface of workpiece 313. In the embodiment, the workpiece 313 similar in performance to the VTR rotary drum 2 of the first embodiment can be completed. Furthermore, the electrode nozzle 319 is a combination of a nozzle and electrode, thereby making compact the entire structure of the tool 301. The surface process tool 301 has a simple structure and is advantage for precise processing.

If powder is supplied through the water glass supply passage 321, it is burnt to stick to inside of the electrode nozzle 319, thereby clogging the passage 321. The electrode nozzle 319 also sticks to the workpiece 313. Yield or process efficiency would be deteriorated. When the powder mixed water glass 323 is supplied to the water glass supply passage 321, however, it is prevented from thermally sticking to the electrode nozzle 319. To the contrary, even if something sticks to the nozzle 319, it can be removed with pressure of discharged powder mixed water glass 323.

In the same manner as in the first embodiment shown in Fig. 1, the electrode 8 and the nozzle 10 can be separately

provided on the tool 301.

This invention has been described above with reference to the preferred embodiments as shown in the figures. Modifications and alterations may become apparent to one skilled in the art upon reading and understanding the specification. Despite the use of the embodiments for illustration purposes, the invention is intended to include all such modifications and alterations within the spirit and scope of the appended claims.

For example, the workpiece 155 or 313 can be heated and melted through ion plating or arc heating.

Industrial water glass No.1, No.2 or No.3 according to Japanese Industrial Standards can be used. The viscosity of the water glass can be adjusted by adding water, such that a desired thickness of water glass can be easily applied to a surface of workpiece corresponding to condition of the surface or dischargeability of a water glass applicator. The water glass can be mixed with a heat resistant inorganic pigment or other coloring agent, or with various additives for transforming glass. Only with the water glass of the aforementioned embodiments, the hardness, smoothness and wear resistance of the workpiece can be enhanced.

In the first to third embodiments, the workpiece 155 or 313 is heated, applied with powder mixed water glass and is then plastically deformed. In the fourth embodiment the workpiece is heated and applied with water glass at the same time and is then plastically deformed. Alternatively, the

workpiece 155 or 313 can be processed by following the procedure of applying of water glass, heating and plastically deforming, such that the same effectiveness as that resulting from the embodiments can be obtained,

The workpiece 155 or 313 of the embodiment is formed of aluminum or aluminum alloy. Alternatively, it can be formed of other metal, glass or ceramic.

In the embodiments, the surface of the VTR rotary drum 2 and the workpieces 155, 313 is processed. Such surface process method can be applied to the inner periphery of a cylinder for an air compressor, an air-conditioner refrigerant gas compressor or an engine or to the outer periphery of a piston for an air compressor, an air-conditioner refrigerant gas compressor or an engine, thereby improving hardness and wear resistance of the peripheries as well as durability of the cylinder and the piston. The surface smoothness of the peripheries is also enhanced, and friction on the peripheries is decreased, thereby minimizing the quantity of energy consumed due to friction. The aforementioned surface process method can be applied to the outer periphery of an electrophotography photosensitive drum, thereby raising hardness and wear resistance of the periphery as well as durability of the drum. Surface smoothness of the periphery is also enhanced, and friction on the periphery is decreased, thereby protecting a printing sheet or a brush from friction with the periphery on which it slides.



WHAT IS CLAIMED IS:

1. A surface process method comprising the steps of:
heating and melting a surface of workpiece;
applying water glass to said surface; and
immediately plastically deforming said surface.
2. A surface process method comprising the steps of:
applying water glass to a surface of workpiece;
heating and melting said surface; and
immediately plastically deforming said surface.
3. A surface process method comprising the steps of:
heating and melting a surface of workpiece;
concurrently applying water glass to said surface; and
immediately plastically deforming said surface.
4. A surface process method according to any one of
claims 1-3, in which said water glass is replaced by water
glass mixed with metal powder.
5. A surface process method according to any one of
claims 1-3, in which said water glass is replaced by water
glass mixed with ceramic powder.
6. A surface process method according to any one of
claims 1-3, in which said water glass is replaced by water
glass mixed with silicon dioxide powder.
7. A surface process method according to claim 4, in
which said metal powder is titanium powder.
8. A surface process method according to claim 5, in
which said ceramic powder is alumina powder.
9. A surface process method according to any one of



claims 1-8, in which said step of plastically deforming is executed by rolling.

10. A surface process method according to any one of claims 1-8, in which said step of plastically deforming is executed by burnishing.

11. A surface process device comprising:

heating means for heating a part of the surface of workpiece;

applying means provided adjacent to said heating means for applying water glass to said part heated by said heating means; and

plastically deforming means provided adjacent to said applying means for plastically deforming said part to which water glass has been applied by said applying means.

12. A surface process device according to claim 11, in which said heating means and said applying means are a plasma discharge electrode having a supply passage for guiding water glass toward the tip thereof.

13. A VTR drum having the outer periphery thereof processed in the surface process method according to any one of claims 1-10.

14. A cylinder having the inner periphery thereof processed in the surface process method according to any one of claims 1-10.

15. A piston having the outer periphery thereof processed in the surface process method according to any one of claims 1-10.



16. A roller having the outer periphery thereof processed in the surface process method according to any one of claims 1-10.

17. An electrophotography photosensitive drum having the outer periphery thereof processed in the surface process method according to any one of claims 1-10.

ABSTRACT OF THE DISCLOSURE

A METHOD OF SURFACE PROCESSING, A SURFACE PROCESS DEVICE, AND A VTR DRUM, CYLINDER, PISTON, ROLLER OR ELECTROPHOTOGRAPHY PHOTOSENSITIVE DRUM WITH THE SURFACE THEREOF PROCESSED

Formation of a glass surface layer having sufficient adhesion to a material and surface smoothness on the surface of material, for enhancing hardness, surface smoothness and wear resistance of the material. By rotating a VTR rotary drum and discharging plasma from an electrode to a periphery of the drum, a melted layer is formed on the periphery. Water glass is discharged from a nozzle to the melted layer, thereby forming a water glass layer. The melted or half-melted part of the melted layer as well as the water glass layer are compressed and plastically deformed with a roller. The water glass layer, cooling down the melted layer, is heated to transform into a glass layer. The glass layer has a sufficiently hard, smooth and dimensionally precise surface. The mixed layer of glass and metal firmly bonds the glass layer to the drum periphery. The VTR drum becomes durable against wear caused by a VTR tape. Since the non-porous and smooth surface is formed on the drum, the tape sliding on the drum is also protected from wear and tear.

This Sheet Has Been Replaced



THIS SHEET HAS BEEN
REPLACED

FIG. 1

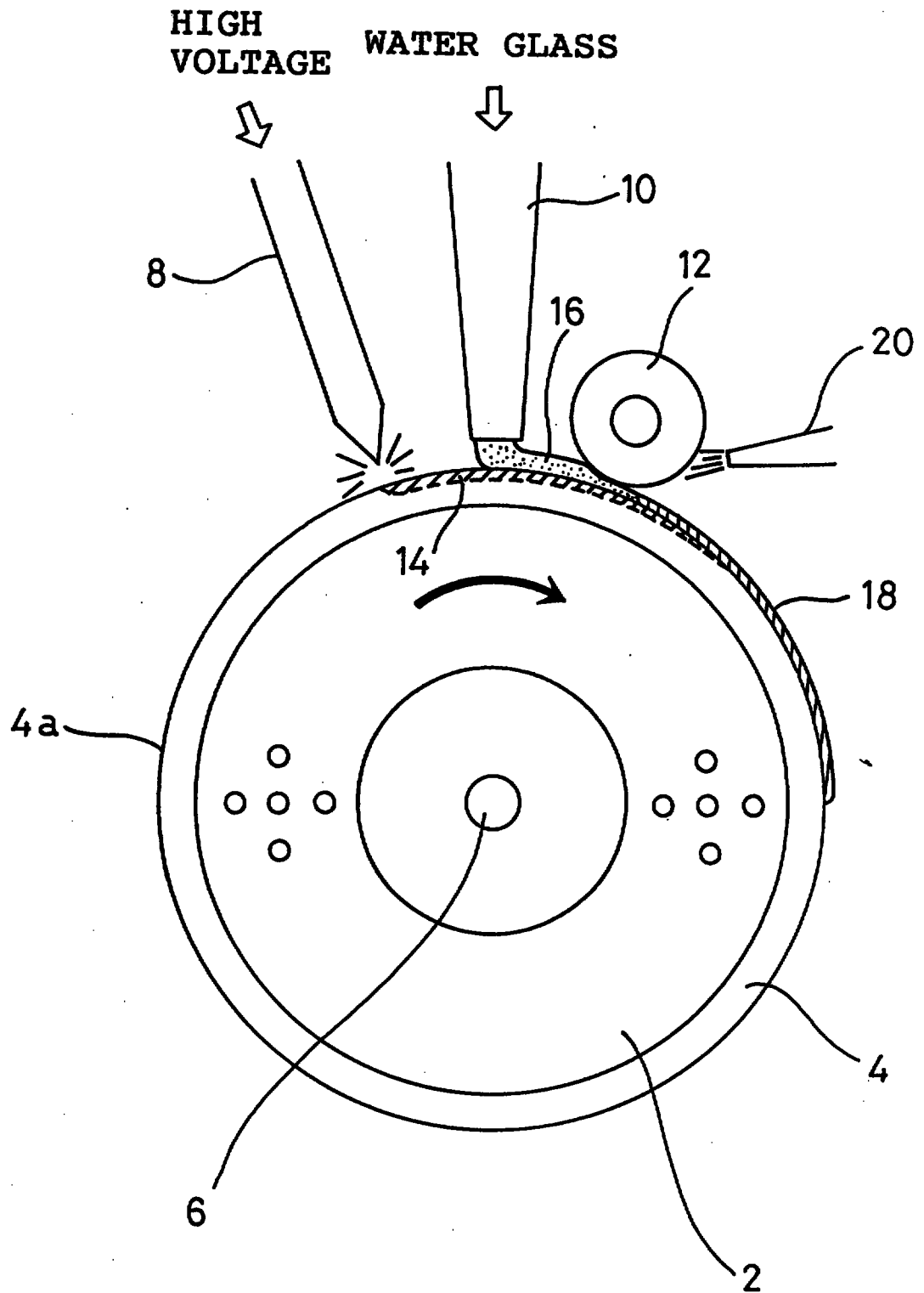


FIG. 2A

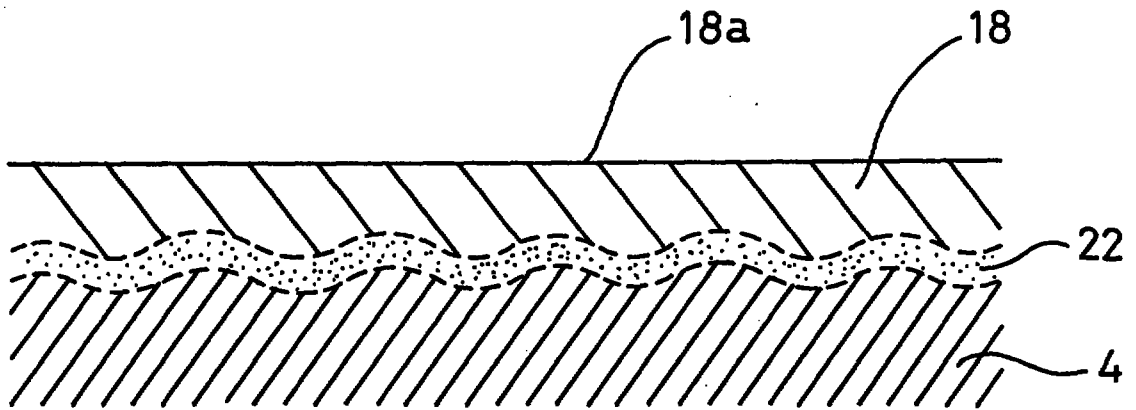


FIG. 2B

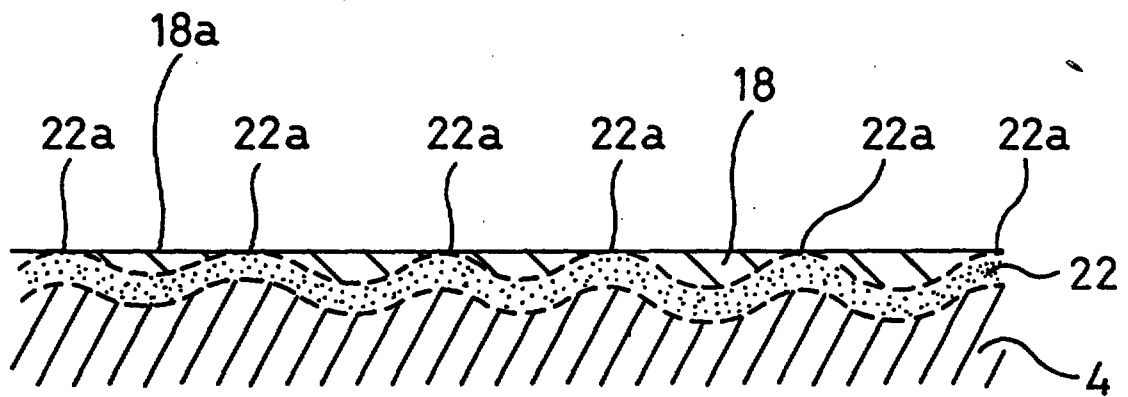


FIG. 3

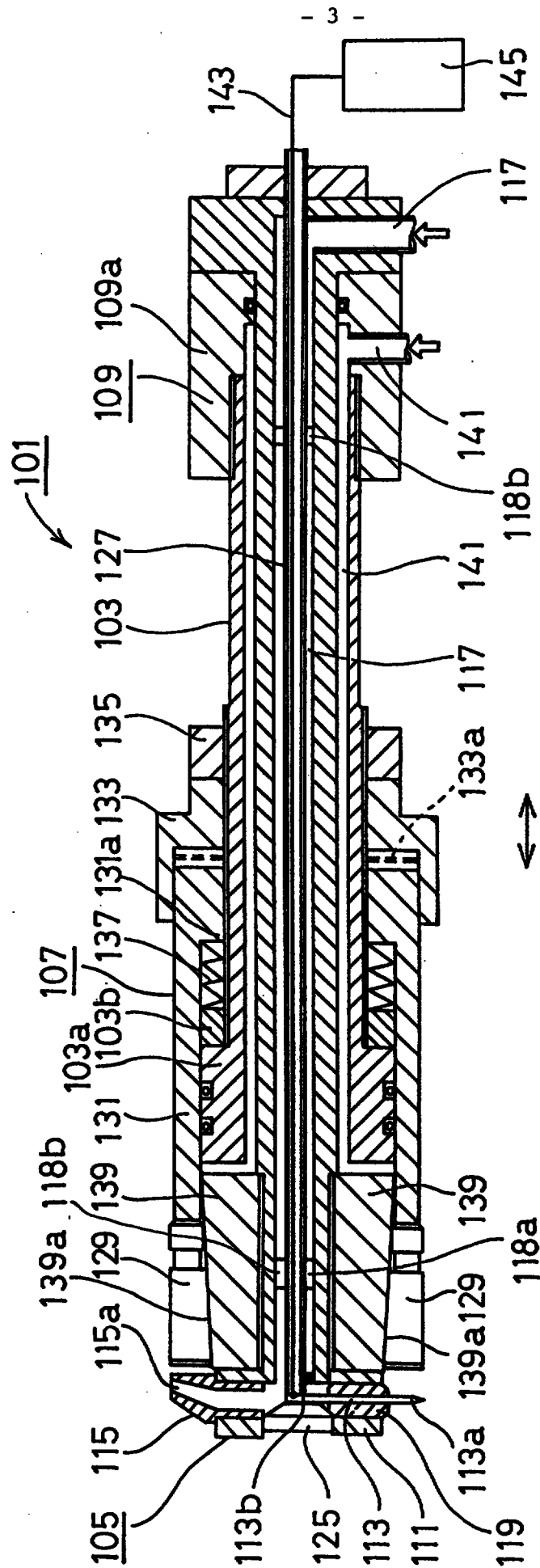


FIG. 4

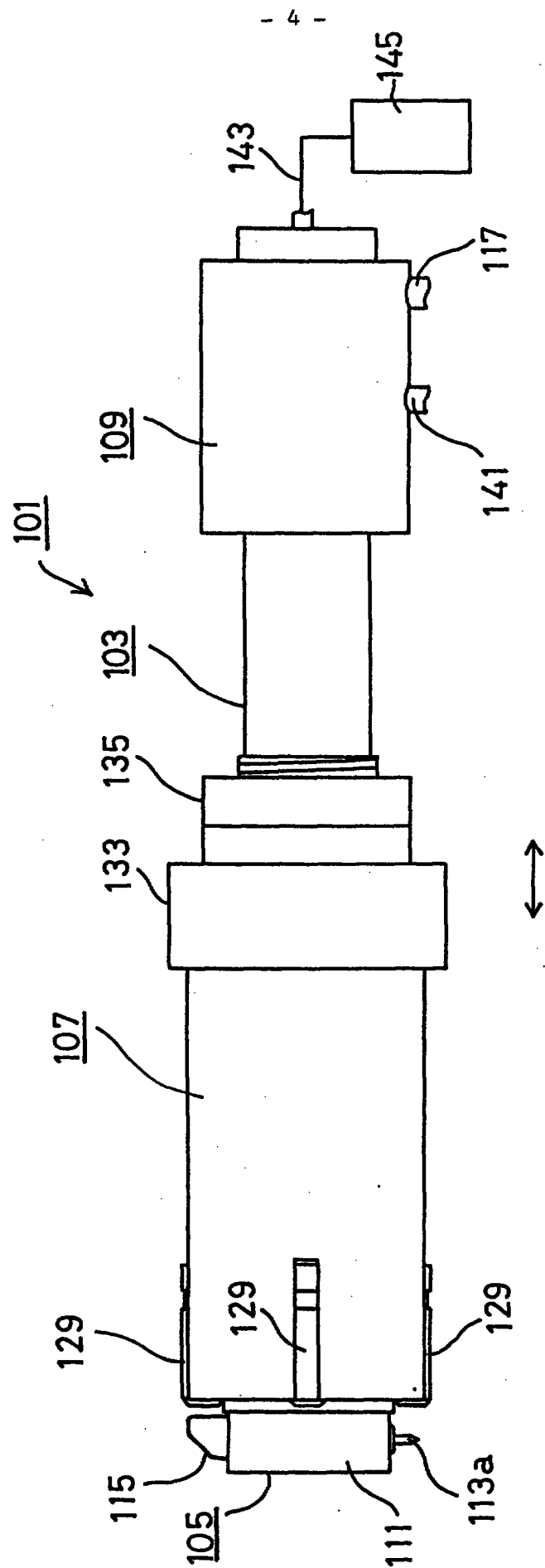


FIG. 5

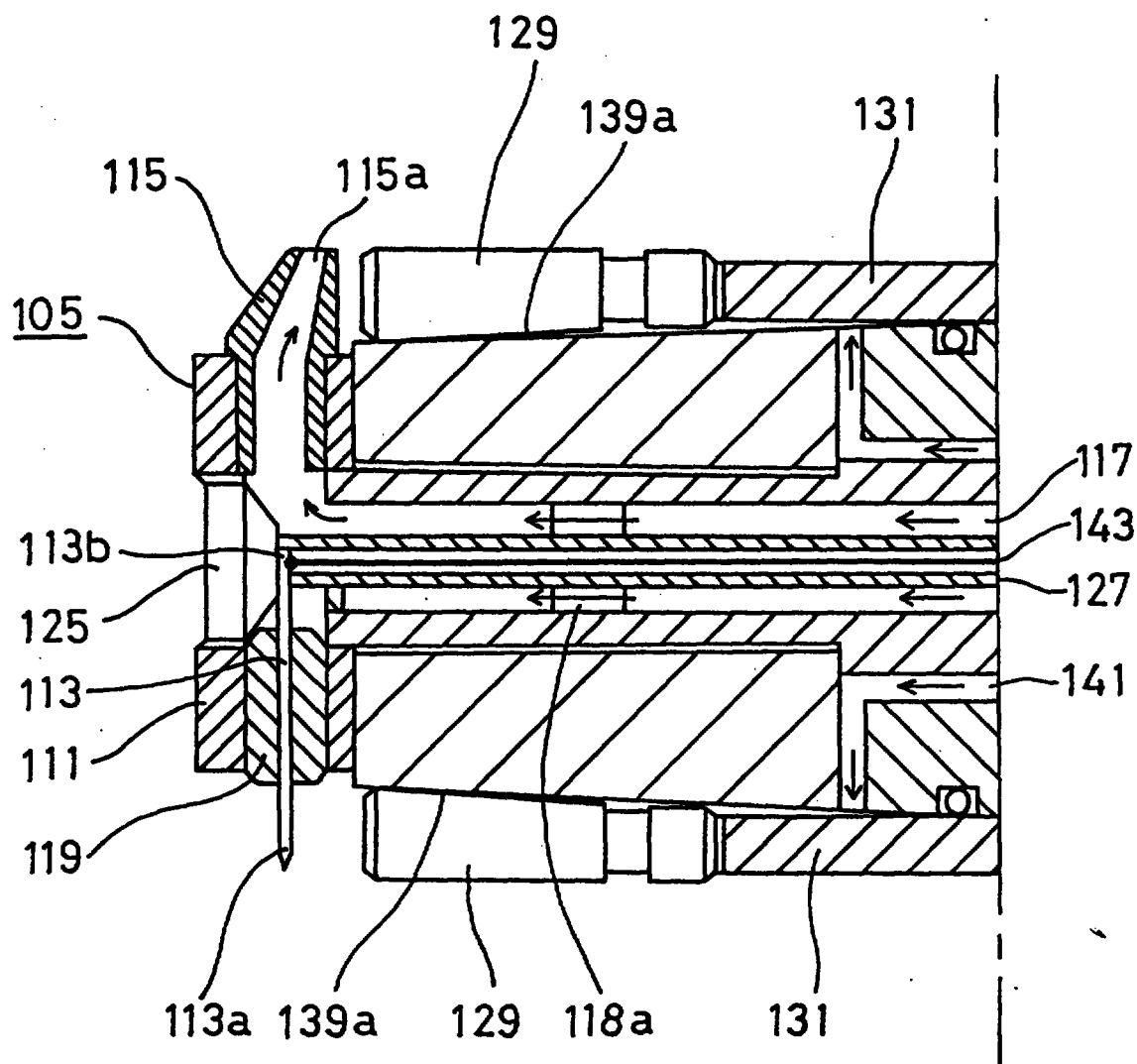


FIG. 6

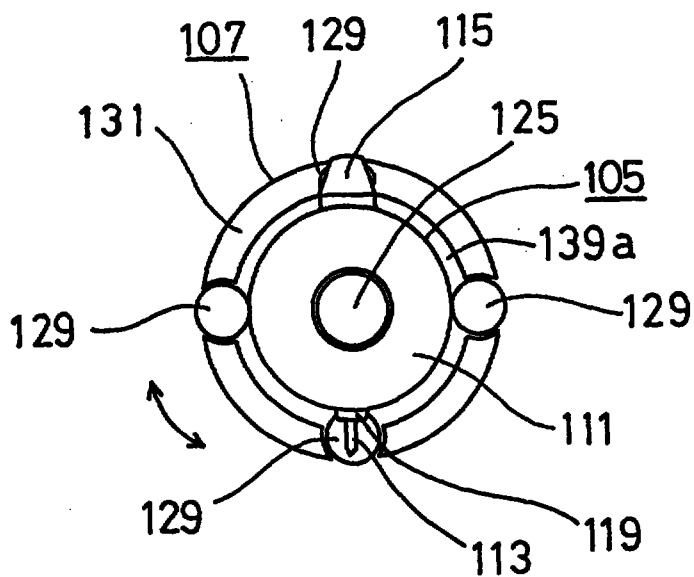


FIG. 7

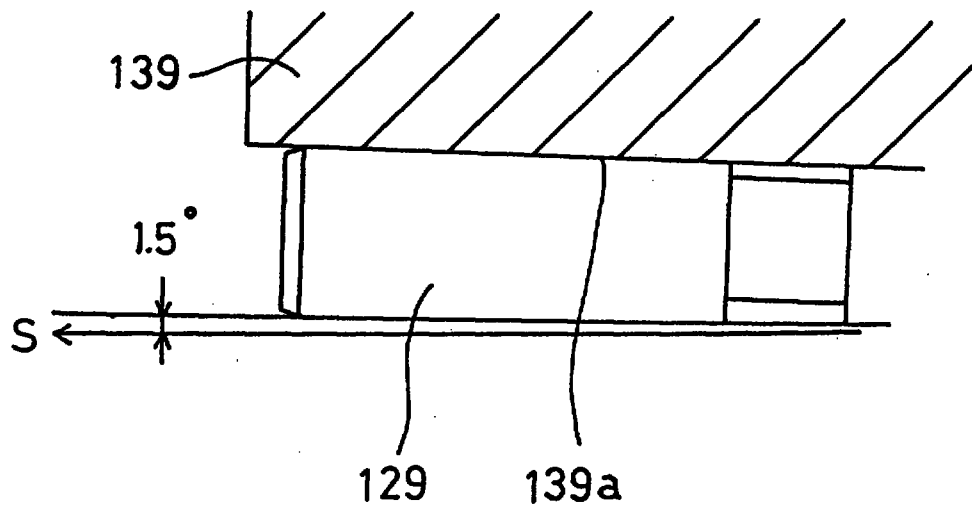


FIG. 8

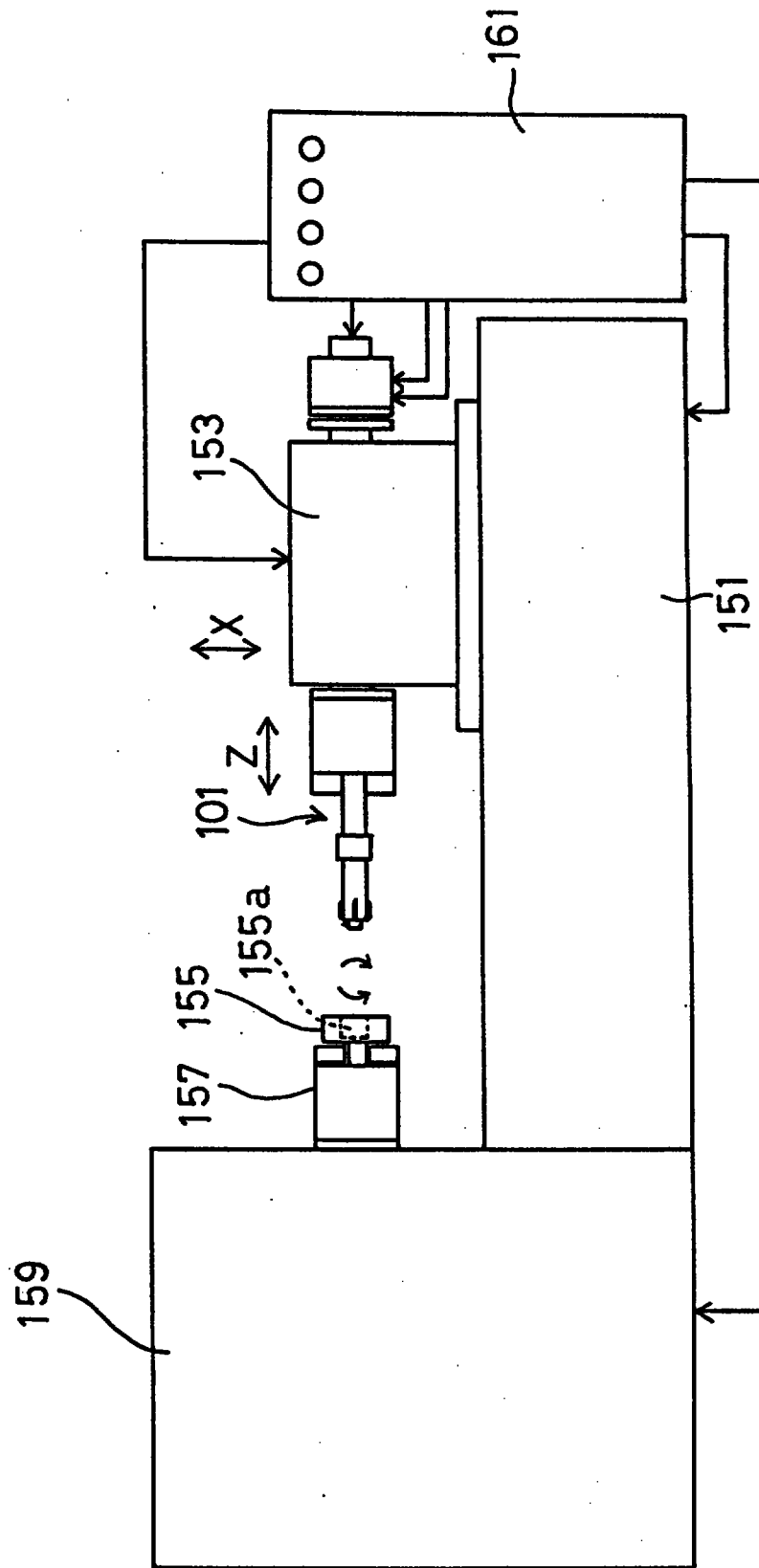


FIG. 9

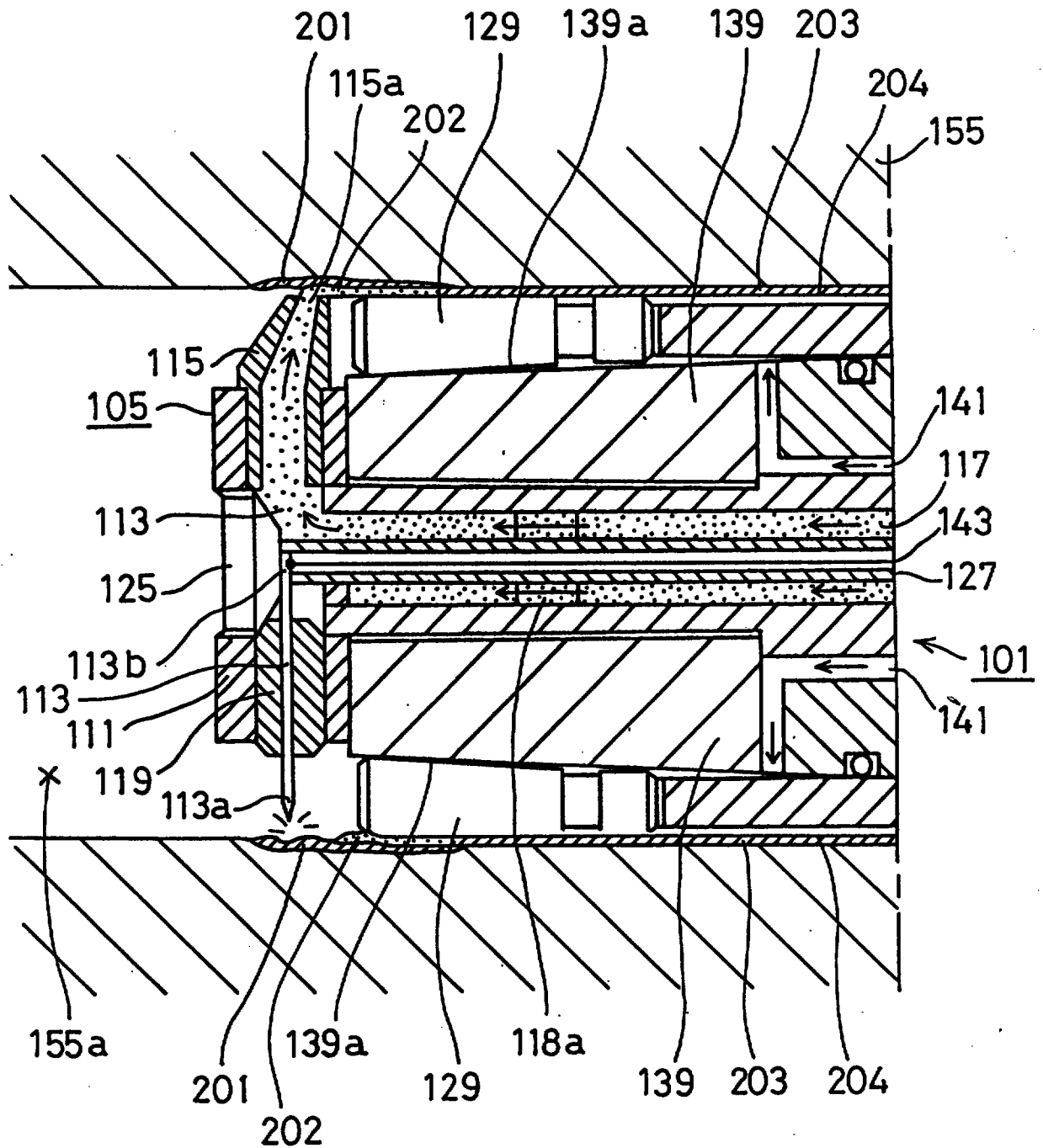


FIG. 11

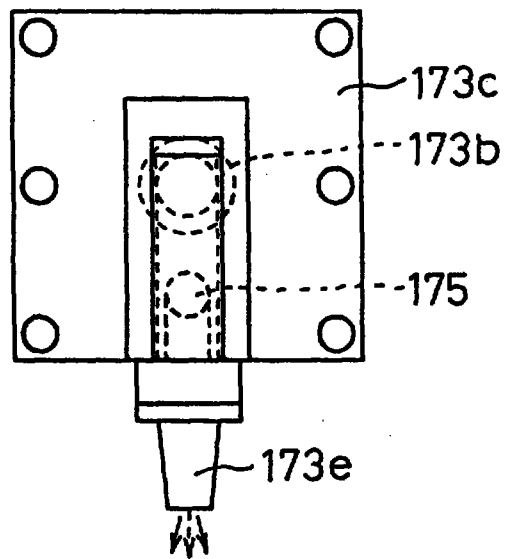


FIG. 12A

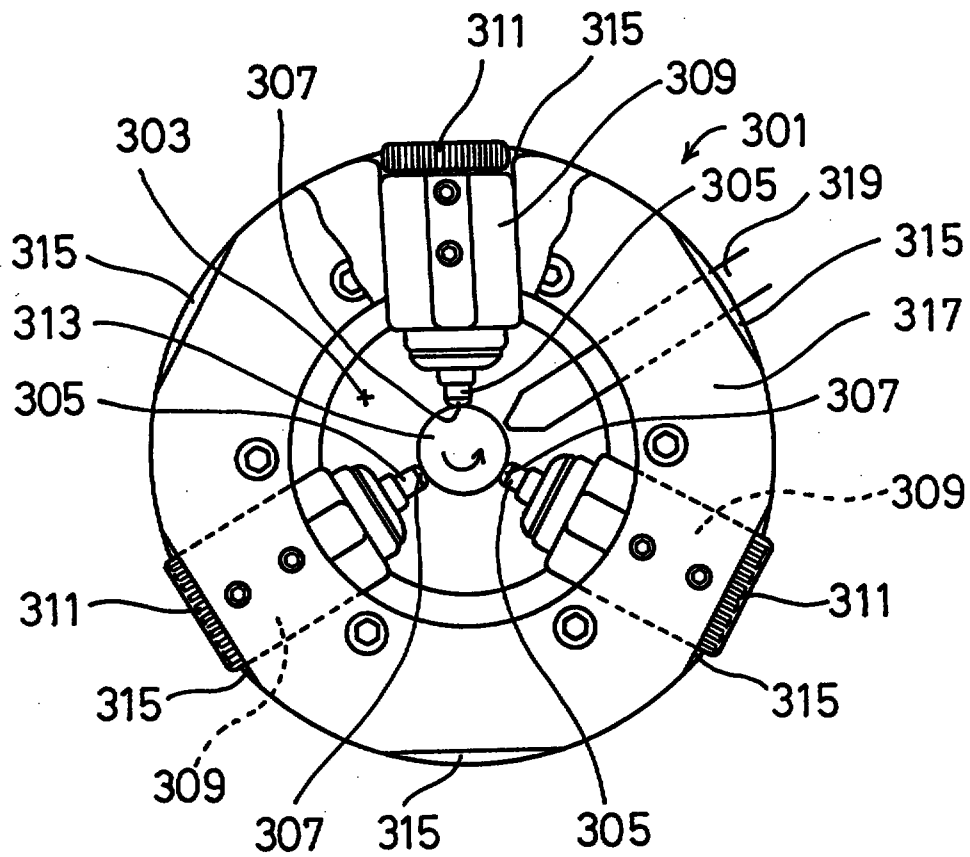
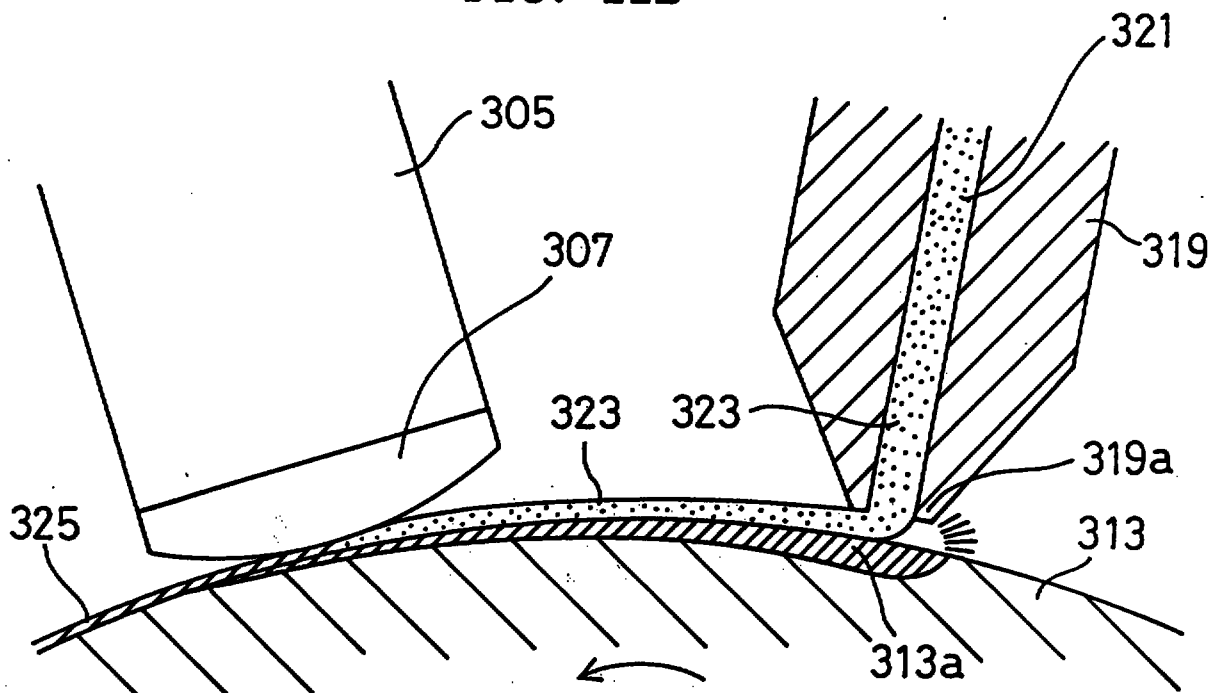


FIG. 12B



ABSTRACT OF THE DISCLOSURE

A METHOD OF SURFACE PROCESSING, A SURFACE PROCESS DEVICE, AND A VTR DRUM, CYLINDER, PISTON, ROLLER OR ELECTROPHOTOGRAPHY PHOTSENSITIVE DRUM WITH THE SURFACE THEREOF PROCESSED

Formation of a glass surface layer having sufficient adhesion to a material and surface smoothness on the surface of material, for enhancing hardness, surface smoothness and wear resistance of the material. By rotating a VTR rotary drum and discharging plasma from an electrode to a periphery of the drum, a melted layer is formed on the periphery. Water glass is discharged from a nozzle to the melted layer, thereby forming a water glass layer. The melted or half-melted part of the melted layer as well as the water glass layer are compressed and plastically deformed with a roller. The water glass layer, cooling down the melted layer, is heated to transform into a glass layer. The glass layer has a sufficiently hard, smooth and dimensionally precise surface. The mixed layer of glass and metal firmly bonds the glass layer to the drum periphery. The VTR drum becomes durable against wear caused by a VTR tape. Since the non-porous and smooth surface is formed on the drum, the tape sliding on the drum is also protected from wear and tear.

FIGURE 1

This is the replacement sheet

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