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Yamamoto

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(54) **SHOT-TREATMENT APPARATUS**

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This patent is subject to a terminal disclaimer.

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B24C 3/20	(2006.01)
B24C 3/08	(2006.01)
B24C 1/10	(2006.01)
B24C 3/22	(2006.01)

(52) **U.S. Cl.**

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(58) **Field of Classification Search**

CPC B24C 1/10; B24C 3/085; B24C 3/086; B24C 3/12; B24C 3/18; B24C 3/20; B24C 3/22; C21D 7/06; B21D 31/06

USPC 72/53; 451/82, 84, 114, 398, 400, 403, 451/413

See application file for complete search history.

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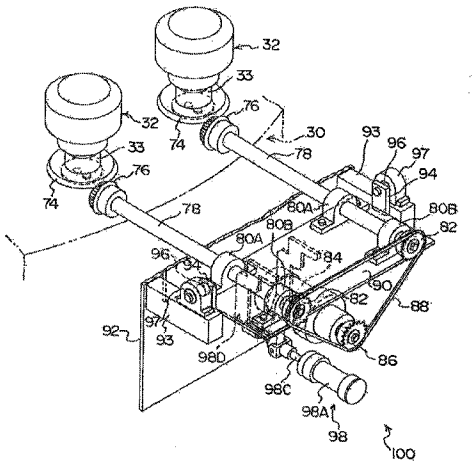
(57) **ABSTRACT**

The present invention aims to provide a shot-treatment apparatus which allows a high throughput of workpieces with the least possible idle time while achieving a uniform shot-treatment effect on workpieces. The shot-treatment apparatus of the present invention has a rotatable main table **30** located in the place where both a projection area to be projected upon by the shot from a projecting device and a non-projection area are included. A plurality of satellite tables **32** for placing workpieces **12** are rotatably mounted on the main table **30**. Each satellite table **32** has a driven shaft **33** which is in parallel with a main shaft **31** of the main table **30**. The shot is projected from the projecting device against the workpiece **12** that is placed on the satellite table **32**. The workpiece **12** that is placed on the satellite table **32** is held down by a holding member **48** of a holding assembly **46**. The holding member **48** rotates along with the workpiece **12**.

8 Claims, 11 Drawing Sheets



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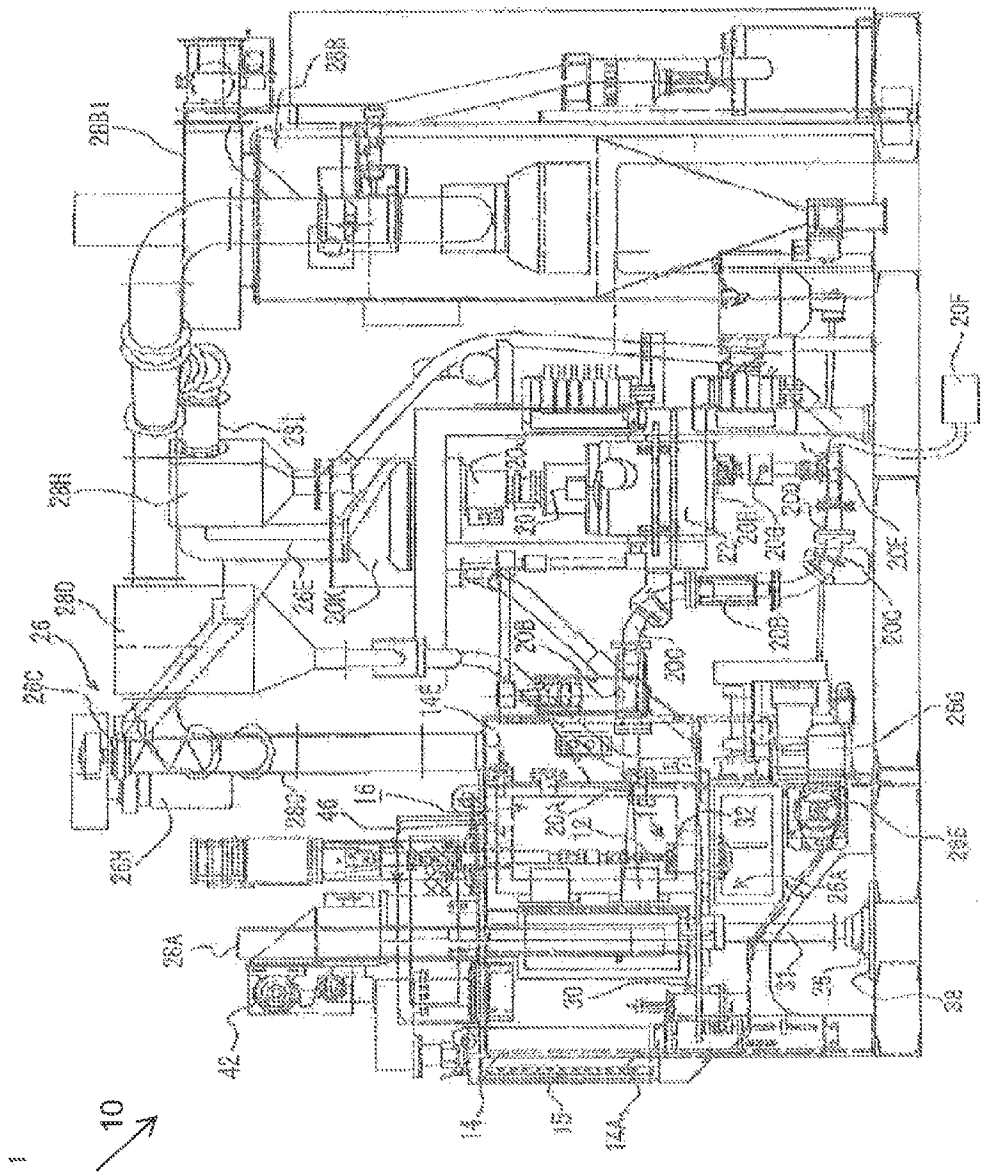
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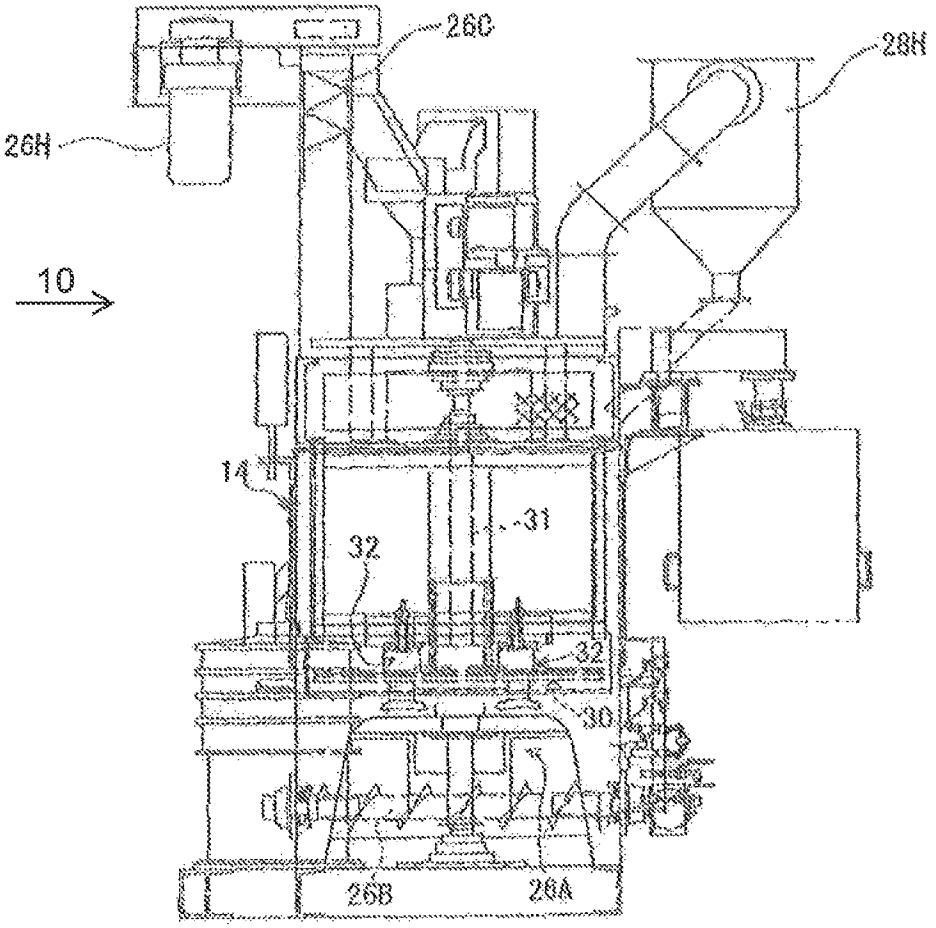
Fig. 1

Fig. 2



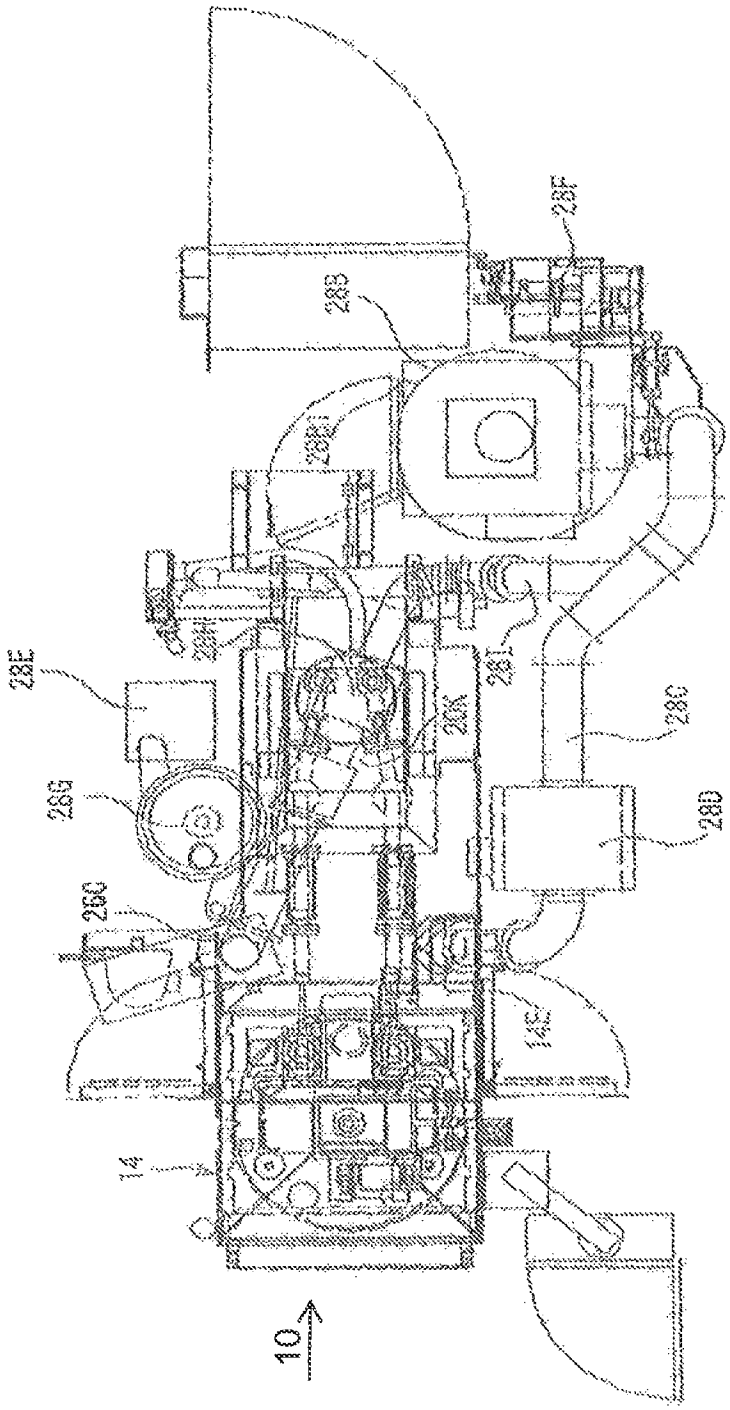


Fig. 3

Fig. 4

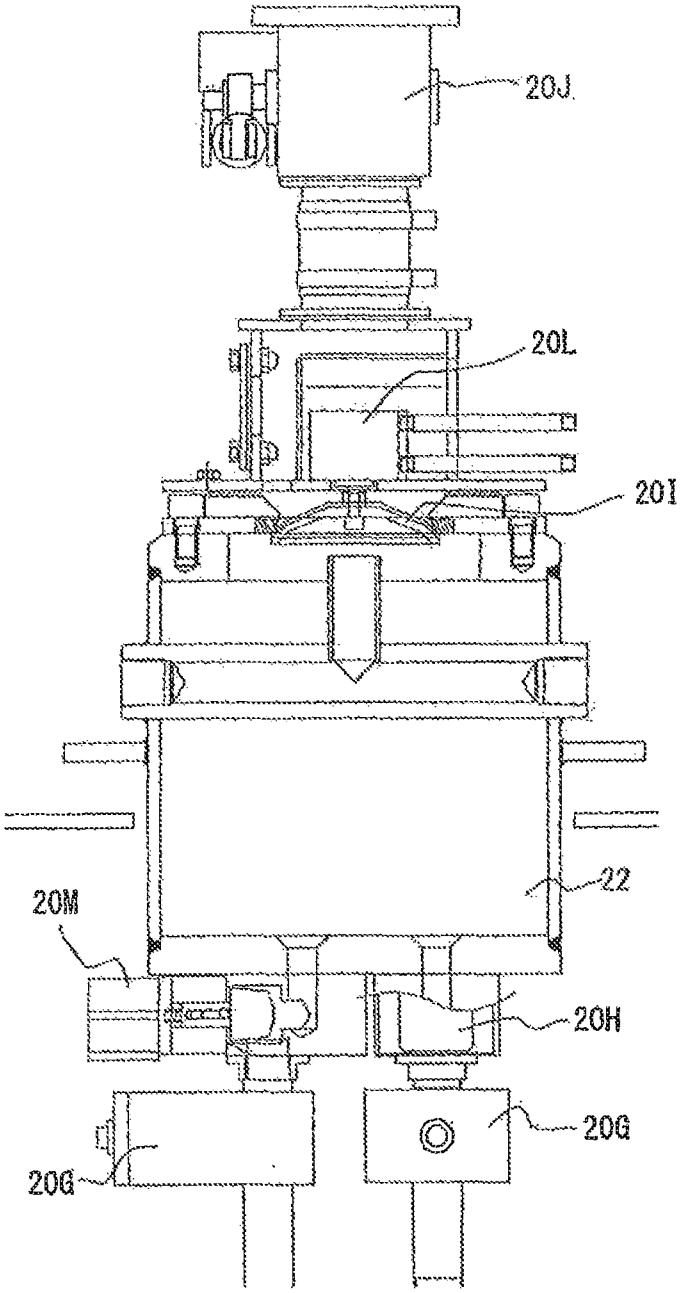
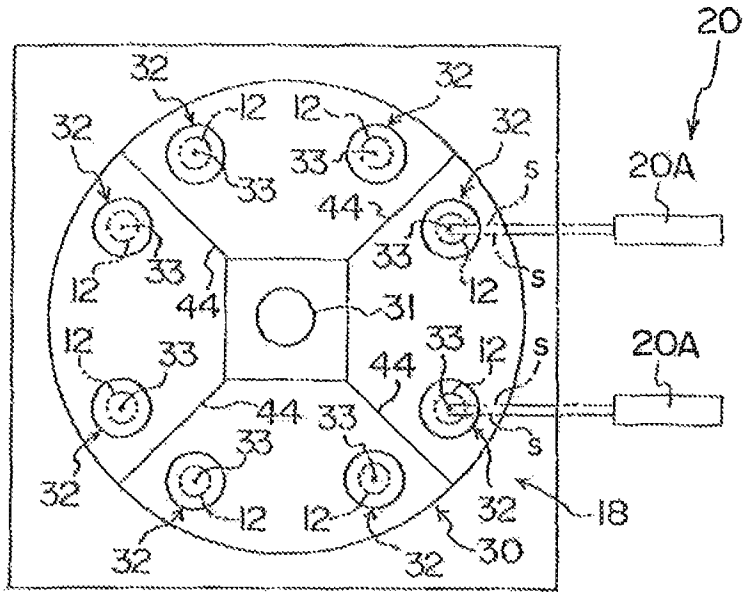


Fig. 5



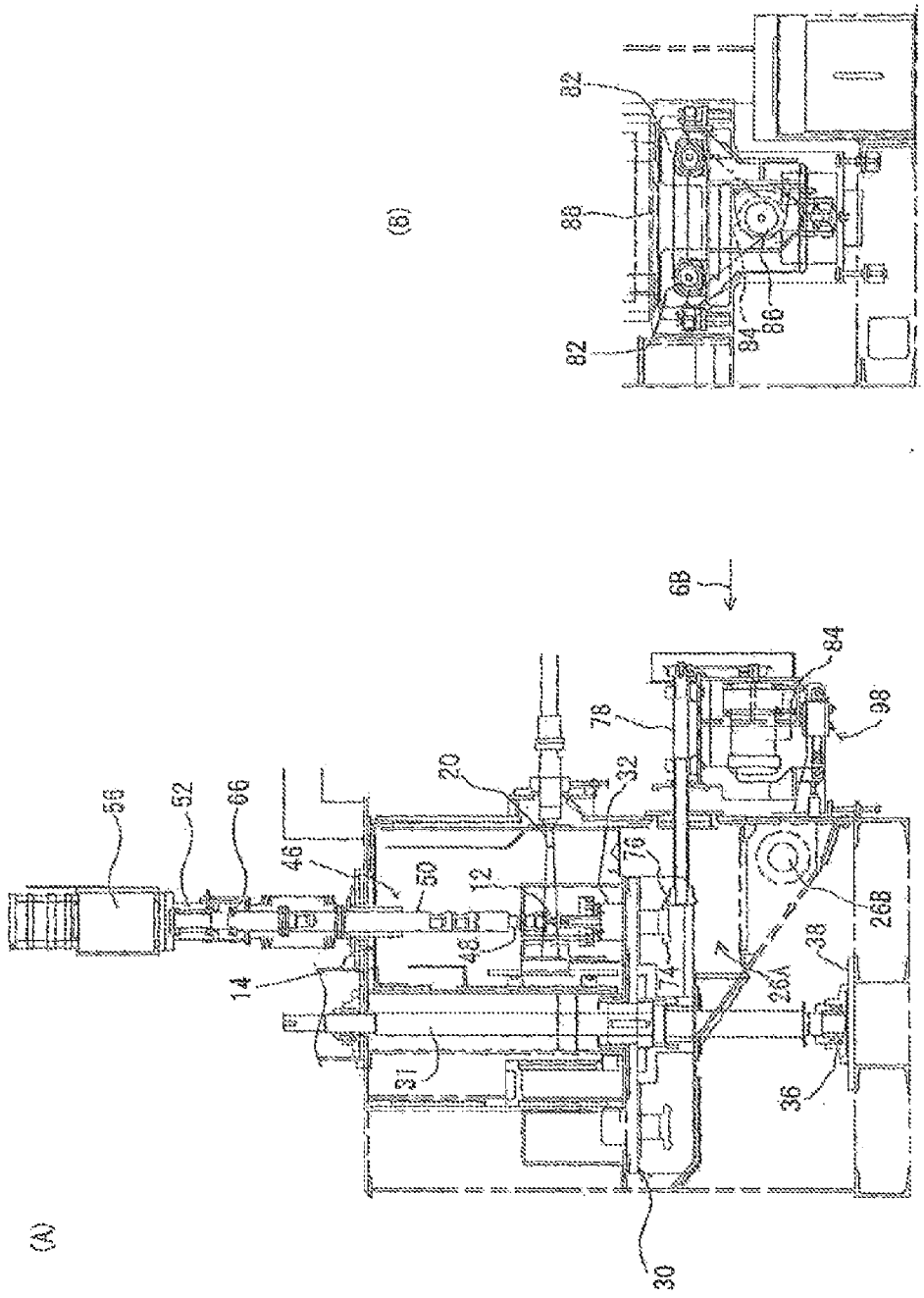

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Fig. 6

Fig. 7

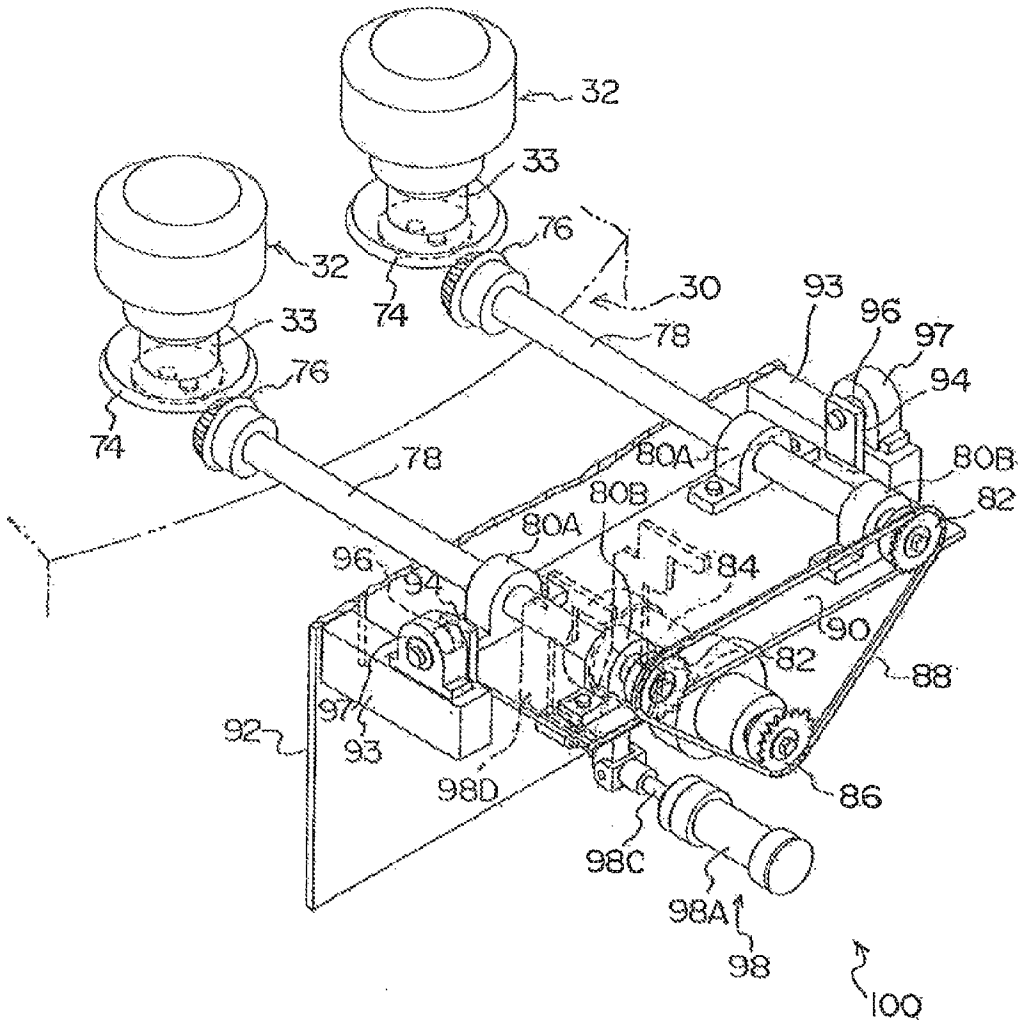
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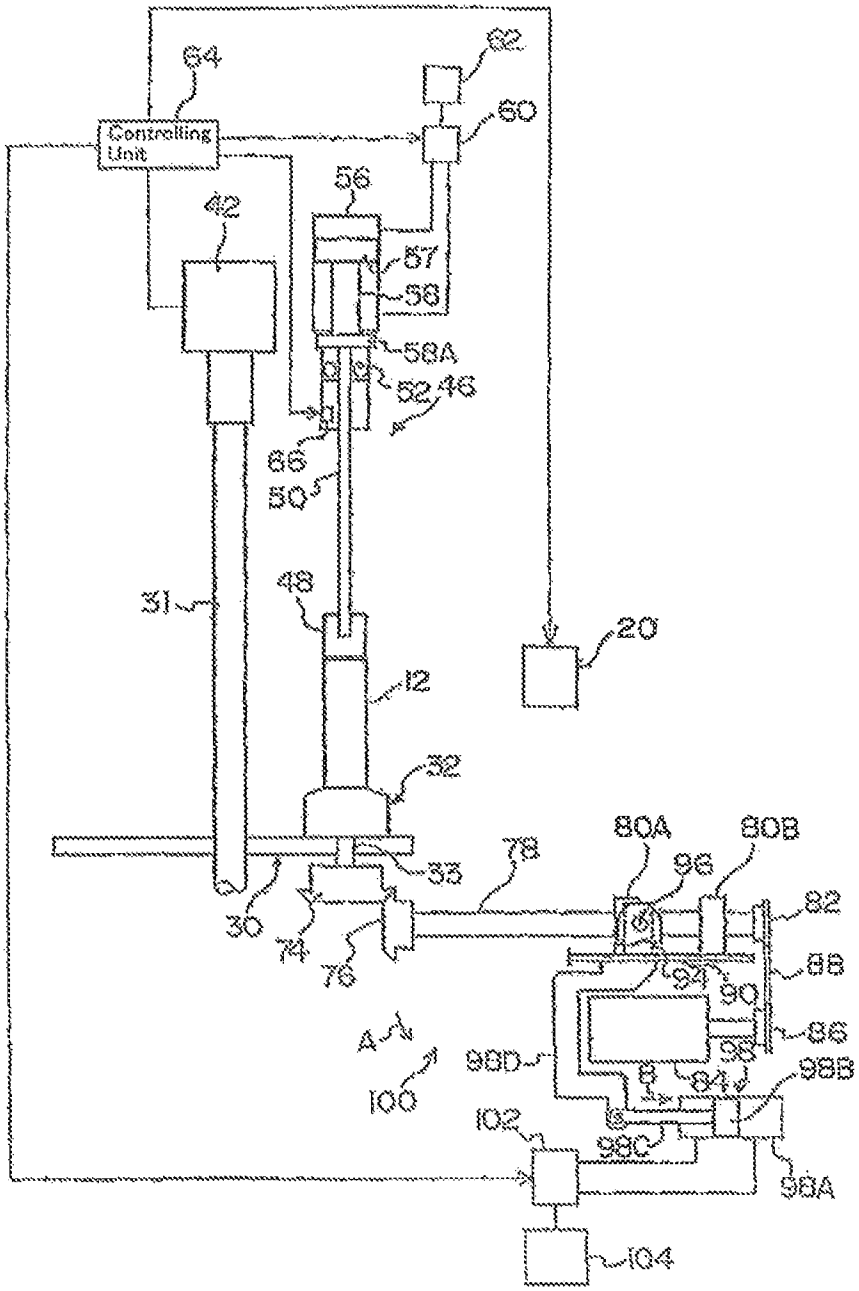
Fig. 8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Controlling Unit
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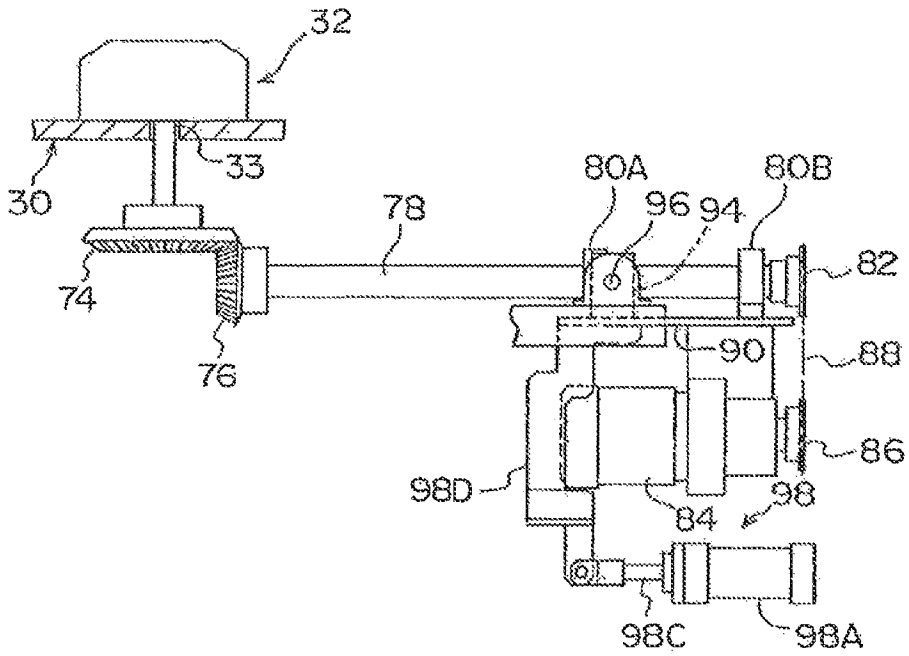
Fig. 9

(A)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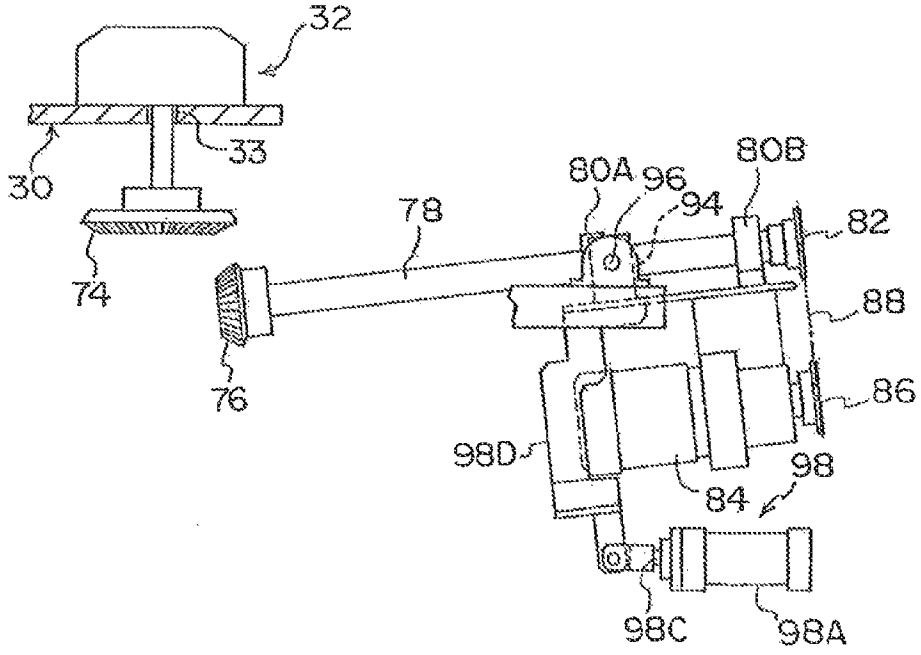
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Fig. 10

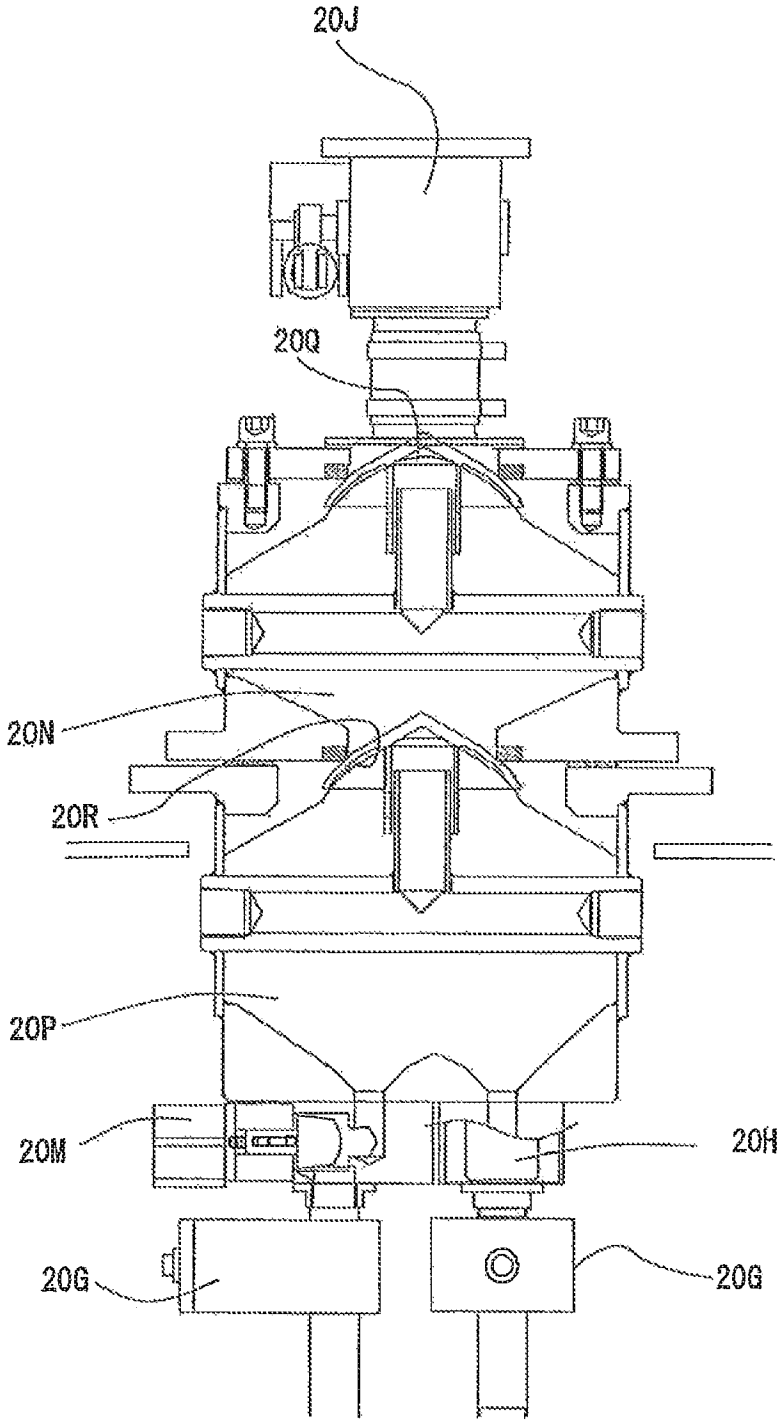
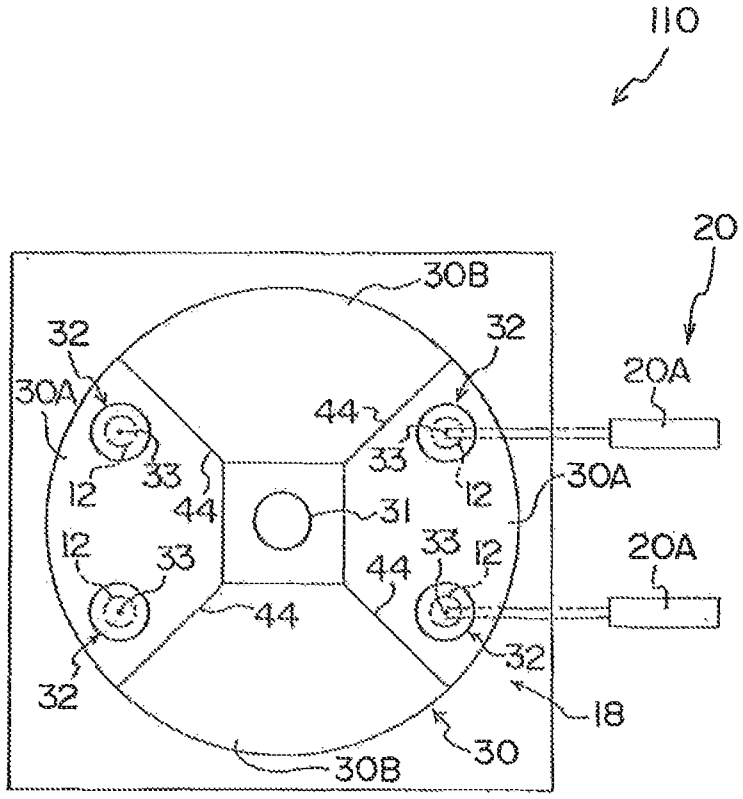


Fig. 11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SHOT-TREATMENT APPARATUS

TECHNICAL FIELD

This invention relates to a shot-treatment apparatus for projecting shot (metallic, glass, or ceramic particles) against a workpiece.

BACKGROUND OF THE INVENTION

There is a type of shot-treatment machine which comprises a table being rotatable in a substantially horizontal plane, and a plurality of workpiece-stages fixed to the table (e.g., see Patent Document 1). Items (i.e., workpieces) placed on the workpiece-stages are blasted when the table is rotating.

CITATION LIST

Patent Literature

Patent Document 1;
Japanese Patent Laid-open Publication No. 2002-96264

SUMMARY OF INVENTION

Technical Problem

However, in this type of prior art machine, a blasting operation needs to be suspended during the loading and unloading operations of the items. Thus, the utilization rate of the machine is not high due to the idle time caused by the loading and unloading operations.

The present invention aims to provide a shot-treatment apparatus which allows a high throughput of workpieces with the least possible idle time while achieving a uniform shot-treatment effect on workpieces.

Solution to Problem

The shot-treatment apparatus of the present invention comprises the following Features: a projecting device for projecting shot with compressed air through a nozzle against a workpiece; a rotatable main table located in a place where both a projection area to be projected by the shot from the projecting device and a non-projection area which is the area other than the projection area are included; a plurality of rotatable satellite tables mounted on the main table, wherein each of the satellite tables for placing workpieces has a driven shaft in parallel with a main shaft of the main table; a holding assembly disposed above the projection area of the main table, wherein the holding assembly holds down the workpiece placed on the satellite table with a holding member which is configured to be rotatable along with the workpiece. Preferably, the satellite tables are arranged in a circle around the main shaft of the main table. When the main table is rotated, one or more satellite tables are positioned in the projection area. Preferably, the holding member holds down the workpiece when at least one satellite table is positioned in the projection area. Further, the holding member rotates about the rotational axis of the satellite table along with the satellite table.

The shot-treatment apparatus of the present invention has the rotatable main table located in the place where both the projection area to be projected upon by the shot from the projecting device and the non-projection area which is the area other than the projecting area are included. A plurality of satellite tables for placing workpieces are rotatably mounted on the main table. Each satellite table has a driven shaft which is in parallel with the main shaft of the main table. The shot is projected through the nozzle of the projecting device against the workpiece with compressed air.

The holding assembly is disposed above the projection area of the main table. The holding member, which is included in the holding assembly, holds down the workpiece placed on the satellite table. The holding member is configured to be rotatable along with the workpiece. By this, the workpiece is secured on the satellite table when it is subjected to a shot-treatment. Further, even when one or more workpieces are subjected to the shot-treatment, other workpieces sitting in the non-projection area can be loaded to and unloaded from the satellite table.

In some embodiments, the shot-treatment apparatus has a rotation-sensing means for detecting the rotation of the holding member.

In this embodiment, when the holding member is rotating along with the workpiece, the rotation-sensing means detects the rotation of the holding member. Accordingly, the apparatus can judge whether a uniform shot-treatment effect on the workpieces is achieved, by detecting the state of the rotation of the workpieces.

In another embodiment, the shot-treatment apparatus further comprises the following features: a driving assembly which rotates the main table about the main shaft in a stepwise manner by a specific angle which is predetermined based on the arrangement of the satellite tables on the main table, so that at least one satellite table is positioned within the projection area when the rotation of the main table is suspended; and a controlling unit which suspends the projection of the shot from the projecting device while the main table is being rotated by the dividing assembly, and resumes the projection of the shot when the rotation of the main table is suspended. Preferably, the control unit lowers the holding member to secure the workpiece on the satellite table before starting the projection of shot. Further, the control unit raises the holding member and suspends the projection of shot before starting the rotation of the main table.

In such an embodiment, the dividing assembly rotates the main table about the main shaft in a stepwise manner by a specific angle which is predetermined based on the arrangement of the satellite tables on the main table. When the rotation of the main table is suspended, at least one satellite table is positioned within the projection area. The controlling unit suspends the projection of the shot from the projecting device while the main table is being rotated by the dividing assembly. Further, the controlling unit resumes the projection of the shot when the rotation of the main table is suspended. By this, any leakage of shot from the apparatus is reduced, and a uniform shot-treatment effect on workpieces is achieved.

In some embodiments, the shot-treatment apparatus further comprises the following features: first mating members disposed on the individual driven shafts extending downward from each of the satellite tables; at least one second mating member located below the main table in the projection area, wherein the second mating member is engageable with any of the first mating members to transmit rotational driving force to the first mating member; and a meshing assembly for engaging the second mating member with the first mating member when the rotation of the main table is suspended, and for disengaging the second mating member from the first mating member before starting the rotation of the main table.

In such embodiments, the satellite table of the shot-treatment apparatus has the first mating member disposed on the driven shaft which is extending downward from the satellite table. The second mating member, which is disposed below

the main table in the projection area, is capable of engaging with the first mating member. The meshing assembly engages the second mating member with the first mating member when the rotation of the main table is suspended. Further, the second mating member transmits a rotational driving force to the first mating member when the second mating member is engaged with the first mating member. The meshing assembly disengages the second mating member from the first mating member before starting the rotation of the main table. By this, when the rotation of the main table is suspended, the workpiece constantly rotates while being secured on the satellite table. As a result, a uniform shot-treatment effect on the entire surface of the workpiece is achieved. Further, the main table is allowed to rotate without interruption when the rotation of the table is resumed.

In some embodiments, the meshing assembly of the shot-treatment apparatus further comprises the following features: a rod member having the second mating member at one end thereof; and a cylinder mechanism for driving the rod member in the direction of disengaging the second mating member from the first mating member.

In such embodiments, the second mating member is disposed at one end of the rod member, and the cylinder mechanism drives the rod member in the direction of disengaging the second mating member from the first mating member. By this, the engagement and disengagement of the first and second mating members are conducted with a simple mechanism.

In some embodiments, the shot-treatment apparatus further comprises a driving motor disposed below the rod member for rotating the second mating member together with the rod member, wherein the rod member is rotated by the motor through a means for transmitting the driving force.

In such embodiments, the second mating member and the rod member are rotated by the driving motor disposed below the rod member through the means for transmitting the driving force from the motor to the rod member. By this, the size of the shot-treatment apparatus is reduced.

In another embodiment, the cylinder mechanism is disposed below the driving motor so that the axis of the cylinder mechanism is in parallel with the rotational axis of the motor.

In such an embodiment, the cylinder mechanism is located below the driving motor so that the axis of the cylinder mechanism is in parallel with the rotational axis of the motor. By this, the size of the shot-treatment apparatus is further reduced.

In some embodiments, the shot-treatment apparatus includes at least one first section and at least one second section alternately formed on the main table by a plurality of walls extending from the inside of the table to the circumference thereof, wherein the first section is provided with the satellite table, and the second section has no satellite table. Preferably, the first and second sections are formed on the main table no as to be rotationally symmetric about the main shaft.

In such embodiments, the shot-treatment apparatus includes at least one first section and at least one second section alternately formed on the main table by a plurality of partitions extending from the inside of the table to the circumference thereof, wherein the first section is provided with the satellite table, and the second section has no satellite table. By this, any leakage of the shot from the apparatus is effectively prevented.

Advantageous Effect of the Invention

As described above, the present invention provides a shot-treatment apparatus which allows a high throughput of workpieces with the least possible idle time while achieving a uniform shot-treatment effect on workpieces.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a right side elevation view of a shot peening apparatus according to a first embodiment of the invention.

FIG. **2** is a front elevation view of the shot peening apparatus according to the first embodiment.

FIG. **3** is a plan view of the shot peening apparatus according to the first embodiment.

FIG. **4** is a partially enlarged view of the pressure tank of the shot peening apparatus and associated facilities thereof, according to the first embodiment.

FIG. **5** is a schematic plan view of the work-table of the shot peening apparatus.

FIG. **6** shows the main part of the shot peening apparatus. FIG. **6**A is a schematic sectional right side view taken through the cabinet of the shot peening apparatus. FIG. **6**A is a schematic side view taken from the direction indicated by the arrow **6**B as in FIG. **6**A.

FIG. **7** is a perspective view of the driving mechanism for satellite tables of the shot peening apparatus according to the first embodiment.

FIG. **8** is a schematic diagram to show a procedure for controlling the shot peening apparatus according to the first embodiment.

FIG. **9** is a schematic diagram to show the engaging/disengaging mechanism of the shot peening apparatus according to the first embodiment. In FIG. **9**A, a second mating member is engaged with a first mating member. In FIG. **9**B, the second mating member is disengaged from the first mating member.

FIG. **10** is a partially enlarged view of an example of the modified pressure tank of the shot peening apparatus and associated facilities thereof, according to the first embodiment.

FIG. **11** is a schematic plan view of a work-table of the shot peening apparatus, according to the second embodiment of the invention.

DESCRIPTION OF EMBODIMENTS

First Embodiment

The shot peening apparatus **10** according to the first embodiment of the invention is described below with reference to FIGS. **1**-**9**. The figures are illustrated as if some outer panels of the cabinet of the apparatus have been removed (or out away). Exemplary workpieces **12** to be treated by the apparatus are mechanical parts, such as gears for an AT (automatic transmission).

FIG. **1** shows a right side elevation of the shot peening apparatus **10**. FIG. **2** shows a front elevation of the apparatus **10**. FIG. **3** shows a plan view of the apparatus **10**.

As in FIG. **1**, the shot peening apparatus **10** has a cabinet **14**. A shot-treatment chamber **16** is disposed in the interior of the cabinet **14**, where shot is projected against the workpiece **12** for performing a surface treatment. The cabinet **14** also has a gateway **14**A formed on the sidewall of the cabinet for transferring the workpiece **12** to and from the chamber **16**. The gateway **14**A is provided with an area sensor **15**.

A work-table **18** for loading the workpieces **12** is disposed at the lower part of the interior of the cabinet **14**. The work-table **18** will be discussed below in detail. A nozzle **20**A of a projecting device **20** is disposed on the side wall of the cabinet **14**. The projecting device **20** projects shot (i.e., particles, e.g., steel balls such as Round Cut Wire available from TOYO

SEIKO K.K.) with compressed air through the nozzle **20**A against the workpiece **12** placed in the shot-treatment chamber **16**. As illustrated in FIG. **8**, the projecting device **20** communicates with a controlling unit **64**. The controlling unit **64** controls the projecting process of the projecting device **20**. The projecting device **20** is described below.

As in FIG. **1**, the nozzle **20**A is connected to a mixing valve **20**E though an abrasion-resistant hose **20**B, a bent pipe **20**C made of cast steel, and a steel pipe **20**D. The mixing valve **20**E is connected to an air source **20**F (depicted as a unit in FIG. **1**), and also connected to a pressure tank **22** through a flow regulator **20**G and a cut-gate **20**H. The shot supplied from the flow regulator **20**G and compressed air supplied from the air source **20**F are mixed in the mixing valve **20**E. The pressure tank **22** is connected to a shot tank **20**K via a constant feeder **20**J and a poppet valve **20**I disposed on the pressure tank **22**. The shot tank **20**K, which is located above the constant feeder **20**J, is for feeding shot to the constant feeder **20**J.

FIG. **4** shows the pressure tank **22** and associated facilities thereof. The pressure tank **22** has a level meter (not shown) for detecting the amount of shot stored in the pressure tank **22**. The level meter is electrically connected to the controlling unit **64** (see FIG. **8**). When the level meter detects that the quantity of shot in the pressure tank **22** is lower than a desired quantity, the controlling unit **64** opens the poppet valve **20**I. Namely, the controlling unit **64** (see FIG. **8**) opens and closes the poppet valve **20**I by actuating a driving cylinder **20**L, which is for operating the poppet valve **20**I, via the signal from the level meter. When the poppet valve **20**I is opened, a desired quantity of shot is supplied to the pressure tank **22** from the shot tank **20**K (see FIG. **1**) through the constant feeder **20**J.

The cut-gate **20**H disposed below the pressure tank **22** is operated by a driving cylinder **20**M. The controlling unit **64** (see FIG. **8**) opens and closes the cut-gate **20**H by actuating the driving cylinder **20**M. For projecting shot from the projecting device **20**, first the pressure tank **22** is filled up with the shot, and then the controlling unit **64** (see FIG. **8**), closes the constant feeder **20**J and the poppet valve **20**I to pressurize the pressure tank **22**. Next, the controlling unit **64** opens the cut-gate **20**H and the flow regulator **20**G while feeding compressed air to the mixing valve **20**E. As a result, the shot flows from the pressure tank **22** to the mixing valve **20**E through the cut-gate **20**H and the flow regulator **20**G. The shot is accelerated by the compressed air in the mixing valve **20**E, conveyed through the steel pipe **20**D, the bent pipe **20**C, and the abrasion-resistant hose **20**B, and then projected through the nozzle **20**A against the workpiece. In this way, the shot peening treatment of the workpiece is accomplished.

The shot peening apparatus **10** further includes a recycling assembly **26** for sending hack the shot projected from the projecting device **20** to the shot tank **20**K. The recycling assembly **26** includes a hopper **26**A, which is disposed under the work-table **18**, for recovering the shot in the cabinet **14**. A screw conveyor **26**B equipped with a driving motor **26**G is disposed under the hopper **26**A.

As in FIG. **2**, the screw conveyor **26**B, which is disposed in a horizontal direction, conveys shot flowing from the hopper **26**A in a longer direction (the traverse direction in FIG. **2**) of the screw conveyor **26**B. At the downstream side of the screw conveyor **26**B (at the left-hand side in FIG. **2**), an inlet of an elevating screw conveyor **26**C is located. The elevating screw conveyor **26**C, which has a driving motor **26**H at the upper end, conveys the shot fed to the inlet above the cabinet **14**.

As illustrated in FIG. **1**, a separator **26**E is provided below the upper end of the screw conveyor **26**C (at the lower right side of the upper end of the conveyor in FIG. **1**). The shot conveyed to the upper end of the conveyor **26**C is transferred to the separator **26**E via a conduit. The separator **26**E is connected to the shot tank **20**K, and is capable of sending only adequate shot back to the shot tank **20**K.

A ventilator **28**A is disposed at the top of the cabinet **14**. An exhaust port **14**E of the cabinet **14** is connected to a duct **28**C. Fine particles generated in the cabinet **14** are sucked out through the exhaust port **14**E and the duct **28**C. The duct **28**C includes a settling chamber **28**D for settling down the fine particles contained in the sucked air. The settling chamber **28**D is connected to the inlet of the elevating screw conveyor **26**C, so that the shot separated in the settling chamber **28**D can be reused. As illustrated in FIG. **3**, the duct **28**C is connected to a dust collector **28**B equipped with a fan **28**B**1**. The dust collector **28**B filters the fine particles contained in the air coming from the settling chamber **28**D and the duct **28**C, so that only air is discharged outside the apparatus.

As illustrated in FIG. **1**, the duct **28**C is connected to the separator **26**E through the settling chamber **28**H and a duct **28**I. By this, the particles sucked out from the separator **26**E are transferred to the dust collector **28**B for filtration, via the settling chamber **28**H and the ducts **28**C, **28**I. As illustrated in FIG. **3**, a waste receiver **28**E is located below the settling chamber **28**H. The waste receiver **28**E receives the fine particles separated in the settling chamber **28**H.

Further, the duct **28**C has a pre-coat feeder **28**F, which is for mixing inactive powders with inflammable powders so that the mixture becomes flame-retardant.

The waste receiver **28**E is connected to a sifter **28**G through a conduit. The sifter **28**G is connected to both the shot tank **20**K and the inlet of the elevating screw conveyor **26**C through separate conduits. The sifter **28**G transfers usable shot contained in the shot coming from the shot tank **20**K to the inlet of the elevating screw conveyor **26**C, and transfers separated fine particles to the waste receiver **28**E.

The details of the work-table **18** are discussed below. FIG. **5** is a schematic plan view of a work-table **18**. FIG. **6** shows a longitudinal sectional view of the main part of the shot peening apparatus **10**.

As illustrated in FIG. **5**, the work-table **18** comprises a rotatable main table **30**, and a plurality of rotatable satellite tables **32** (eight tables, in this embodiment) which are arranged in a circle around the main shaft **31** of the main table **30**. Thus, the work-table **18** is configured as a so called multiple table. The main table **30** rotates about the main shaft **31**, which runs vertically through the main table **30**. The main table **30** is located in the place where both the projection area to be projected by the shot and the non-projection area are included. In FIG. **5**, the boundaries of the projection area are indicated by two-dot chain lines S. The diameter of the satellite table **32** for placing a workpiece **12** is smaller than that of the main table **30**. The satellite table **32** rotates about a driven shaft **33**, which extends in parallel with the main shaft **31** of the main table **30**. Further, the satellite tables **32** rotate around the main shaft **31** together with the main table **30**.

As in FIG. **6**A, the lower end of the main shaft **31** is mounted on a base member **38** via a shaft bearing **36**. The upper end of the main shaft **31** is connected to a dividing assembly **42** (see FIG. **1**) via a coupling member.

Since a variety of dividing assemblies are well known, detailed drawings of the dividing assembly **42** are omitted. In this embodiment, the dividing assembly **42** comprises a motor equipped with a brake for rotating the main table **30** in a stepwise manner, a positioning clamp for holding the main table at a specific rotational angle, and a positioning cylinder for operating the positioning clamp. By this, the dividing assembly **42** rotates the main table **30** about the main shaft **31**

in a stepwise manner by the specific angle (90 degrees, in this embodiment) which is predetermined based on the arrangement of the satellite tables. When the main table **30** is rotated by the specific angle, the dividing assembly **42** temporarily stops the rotation of the main table **30** by means of the positioning clamp. Thus, the dividing assembly **42** rotates the main table **30** in a stepwise manner by the specific angle which is predetermined based on the arrangement of the satellite tables. Further, the dividing assembly **42** temporarily stops the rotation of the main table **30**, so that at least one satellite table **32** (two tables, in this embodiment) is positioned in the projection area (see FIG. **5**). The dividing assembly **42** can be constructed using, for example, a cam mechanism (e.g., INDEXMAN™, available from CKD.KK) and a motor equipped with a reducer.

With reference to FIG. **8**, the dividing assembly **42** communicates with a controlling unit **64**. The controlling unit **64** suspends the projection of shot from the projecting device **20** while the main table **30** is rotating, and resumes the projection of shot from the projecting device **20** when the rotation of the main table **30** is suspended.

As in FIG. **5**, when the rotation of the main table **30** is suspended, the satellite tables are positioned at the following locations: the projection area to be projected upon by the shot (projection zone); a loading/unloading zone where the workpieces are transferred to and from the satellite tables **32** (the left-hand side in FIG. **5**); and another zone which is included in the non-projection area. On the main table **30**, a plurality of sections are formed by a plurality of walls **44** (four walls, in this embodiment) extending from the inside of the table to the circumference. In some embodiments, the walls **44** may have sealing members to seal the gaps between the walls **44** and the surrounding part. In some embodiments, to avoid a collision between the sealing members and the walls **44**, the sealing members are contracted by the controlling unit while the main table **30** is rotating.

As in FIG. **6**A, a holding assembly **46** (a holding device) is disposed above the projection area of the main table **30**. The holding assembly **46** has a holding member **48** for holding down the workpiece **12** placed on the satellite table **32**. The holding member **48** is fixed to the lower end of a holding shaft **50**. The holding shaft **50** comprises a plurality of rods connected in series. The upper end of the holding shaft **50** is supported by a shaft bearing **52** which is fixed to a coupling member **58**A disposed at the lower end of a rod **58** (see FIG. **8**). The holding shaft **50**, which is supported by the shaft bearing **52**, is rotatable about the axis of thereof. However, the holding shaft **50** is not allowed to move up or down with respect to the rod **58** and the shaft bearing **52**. Accordingly, the holding member **48** is not only rotatable about the axis of the holding shaft **50**, but also rotatable along with the workpiece **12** and the satellite table **32** when the holding member **48** is holding down the workpiece **12**. Since the lower part of the holding shaft **50** may be abraded by the shot, the lower part is configured to be exchangeable (i.e., comprising a plurality of rods connected in series), as in FIG. **6**A.

As in FIG. **8**, a part of a rod **58**, and a piston **57** which is connected to the upper end of the rod **58**, are disposed within a cylinder **56**. The cylinder **56** is fixed to the ceiling of the cabinet **14** (see FIG. **1**) by a linking member (not shown). The piston **57** and the rod **58** are moved up and down by means of fluid pressure (e.g., pneumatic pressure, in this embodiment) applied to the cylinder **56**. Thus, when the rod **58** is moved up and down, the holding assembly **46**, the shaft bearing **52**, the holding shaft **50**, and the holding member **48**, are also moved up and down. In this embodiment, the piston **57** and the rod **58** are moved up down by the cylinder **56** fixed to the ceiling of the cabinet **14**. Alternatively, the rod may be fixed to the ceiling of the cabinet so that the cylinder moves up and down. By this, the shaft bearing **52**, the holding shaft **50**, and the holding member **48** are also allowed to move up and down.

The cylinder **56** of the holding assembly **46** is connected to an air source **62** through an air-direction regulator (e.g., a solenoid valve) **60** which communicates with the controlling unit **64**. The controlling unit **64** moves the piston **57** and the rod **58** up and down by controlling the air-direction regulator **60**.

Accordingly, the holding member **48** is allowed to move down to contact the top of the workpiece **12**. When the workpiece **12** is rotated about a vertical axis, the holding member **48** is rotated along with the workpiece **12**.

As in FIG. **6**A, the holding assembly **46** has a rotation-sensing means **66** which is mounted on the upper part of the holding shaft **50** and located slightly below the shaft bearing **52**. The rotation-sensing means **66** detects the rotation of the holding shaft **50**, i.e., the rotation of the holding member **48**. As in FIG. **8**, the rotation-sensing means **66** communicates with the controlling unit **64**. When the rotation-sensing means **66** does not detect the rotation of the holding member **48** although the rotation of the main table **30** is suspended (i.e., the bolding member **48** is supposed to be rotating), the controlling unit **64** warns an operator that there is no rotation of the workpiece, via a warning means (not shown). The controlling unit **64** judges the rotational state of the main table **30** based on the information from the dividing assembly **42**. The warning means for warning the operator is an alarm display or an audible alarm.

As in FIG. **7**, the driven shaft **33**, extending downward from the satellite table **32**, has a first mating member **74**, which is concentrically fixed to the lower end of the driven shaft **33**. The first mating member **74** has a bevel gear-like shape. Further, in the projection area, a second mating member **76**, engageable with the first mating member **74**, is disposed below the main table **30**. The second mating member **76** also has a bevel gear-like shape. Thus, the first and second mating members **74**, **76** have an engagement mechanism similar to a gear mechanism. The teeth of the first and second mating members **74**, **76** are designed to be big enough to prevent disengagement when a certain amount of shot has entered between the teeth.

The second mating member **76**, which is concentrically fixed to one end of a rod member **78**, has a smaller diameter than the first mating member **74**. However, the diameter of the second mating member **76** can be the same as that of the first mating member **74** (i.e., miter gears having the same number of teeth can be used). The rod member **78**, which is rotatably supported by the shaft bearings **80**A, **80**B, has a chain wheel **82** fixed to the end opposed to the second mating member **76**. A driving motor **84**, fixed to the lower surface of a base plate **90** by a fixing means, is located below a pair of rod members **78** and closer to the chain wheel **82** (see FIG. **6**B) than the second mating member **76**. The driving motor **84** has a lower chain wheel **86** concentrically fixed to the drive shaft thereof. The lower chain wheel **86** is located just below the chain wheel **82**. The lower chain wheel **86** is coupled to the chain wheel **82** by an endless chain **88**. Accordingly, the driving motor **84** rotates the second mating members **76** by rotating the pair of rod members **78** through the lower chain wheel **86**, the chain **88**, and the chain wheel **82**. Further, the second mating members **76** rotate the first mating members **74**, when these mating members are engaged.

The second mating members **76** are combined with a meshing assembly **100** for conducting the engagement and disengagement of the first and second mating members **74**, **76**. The

meshing assembly **100**, which includes the rod member **78**, engages the second mating members **76** with the first mating members **74** when the rotation of the main table **30** is suspended, and disengages the second mating members **76** from the first mating members **74** before starting the rotation of the main table **30**. The meshing assembly **100** will be discussed below in detail.

The shaft bearings **80**A, **80**B for supporting a pair of the rod members **78** are fixed to a base plate **90**. The base plate **90** has a pair of brackets **94** which are arranged so that the pair of shaft bearings **80**A is located between them. Each bracket **94** has a pin **96**, which is rotatably supported by a pin-support member **97**. The pair of pins **96** is arranged on the same imaginary horizontal axis which is perpendicular to the rotational axes of the rod members **78**. The pin-support member **97** is fixed to a longitudinal base plate **92** via a connecting part **93**.

As in FIGS. **6**A and **7**, an air cylinder **98** (a cylinder mechanism) is disposed below the driving motor **84**. The axis of the air cylinder **98**, which extends in the same direction as the axes of the rod members **78**, is parallel to the axis of the driving motor **84**. As illustrated in FIG. **8**, the air cylinder **98** includes, in a cylinder **98**A, a piston **98**B, which is moved along the axis of cylinder **98**A by pneumatic pressure (or fluidal pressure) supplied to the cylinder. The piston **98**B is connected to the proximal end of a rod **98**C of the cylinder **98**. The distal end of the rod **98**C is rotatably connected to one end of an arm **98**D. Another end of the arm **98**D is fixed to the lower surface of the base plate **90** at the location between the second mating members **76** and the imaginary horizontal axis of the pins **96**.

The air cylinder **98** of a meshing assembly **100** is connected to an air source **104** via an air-direction regulator **102** (e.g., a solenoid valve) which communicates with the controlling unit **64**. The controlling unit **64** controls the expansion and contraction of the air cylinder **98** by controlling the air-direction regulator **102** based on the information from the dividing assembly **42**. In this embodiment, the meshing assembly **100** disengages the second mating member **76** from the first mating member **74** by actuating the air cylinder **98** so that the rod member **78**, which has the second mating member **76**, rotates about the pin **96** in a direction (a direction indicated by the arrow A as in FIG. **8**) to be away from the first mating member **74** (see FIG. **9**B).

The operation and the effect of the shot peening apparatus **10** of the above embodiment is discussed below.

As illustrated in FIG. **5**, the rotatable main table **30** is located in the place where both the projection area to be projected upon by the shot from the projecting device **20** and the non-projection area other than the projection area are included. A plurality of rotatable satellite tables **32** for placing workpieces **12** are mounted on the main table **30**. Each satellite table **32** has a driven shaft **33** which is in parallel with the main shaft **33** of the main table **30**. Further, the shot is projected from the projecting device against the workpiece **12** placed on the satellite table **32** for treating the surface of the workpiece **12**.

As illustrated in FIG. **6**A, the holding assembly **46** is disposed above the main table **30** in the projection area. The holding member **48** included in the holding assembly **46** holds down the workpiece **12** placed on the satellite table **32**. The holding member **48** is configured to be rotatable along with the workpiece **12**. By this, the workpiece **12** is stably held on the satellite table **32** when it is subjected to a shot-treatment. Further, even when one or more workpieces **12** are subjected to the shot-treatment, other workpieces **12** located in the non-projection area (loading and unloading zone) can be loaded to and unloaded from the satellite table **32** (the left-hand side of FIG. **5**).

When the holding member **48** as in FIG. **6**A rotates along with the workpiece **12**, the rotation-sensing means **66** detects the rotation of the holding member **48**. When the rotation-sensing means **66** does not detect the rotation of the holding member **48** although the rotation of the main table **30** is suspended (i.e., the holding member **48** is supposed to be rotating), the controlling unit **64** as in FIG. **8** warns an operator that there is no rotation of the workpiece **12** through a warning means (not shown). The controlling unit **64** judges the rotational state of the main table **30** based on the information from the dividing assembly **42**. The warning means gives a warning to the operator with an alarm display or an audible alarm. Thus, the shot peening apparatus **10** can judge whether a uniform shot peening effect on the workpieces **12** is achieved.

The dividing assembly **42** rotates the main table **30** about the main shaft **31** in a stepwise manner by a specific angle (90 degrees in this embodiment) which is predetermined based on the arrangement of the satellite tables **32**. When the rotation of the main table **30** is suspended, at least one satellite table **32** (two satellite tables, in this embodiment) is positioned within the projection area. Further, the controlling unit **64** suspends the projection of the shot from the projecting device **20** while the main table **30** is being rotated by the dividing assembly **42**, and resumes the projection of the shot when the rotation of the main table **30** is suspended. By this, any leakage of the shot from the apparatus is reduced. Further, a uniform shot peening effect on workpieces **12** is achieved.

In this embodiment, the satellite table **32** has the first mating member **74**, which is disposed on the driven shaft **33** extending downwardly from the satellite table **32**. The second mating member **76**, which is located below the main table **30** in the projection area, is capable of engaging with the first mating member **74**. The second mating member **76** transmits a rotational driving force to the first mating member **74**, when the second mating member **76** engages with the first mating member **74**. The meshing assembly **100** engages the second mating member **76** with the first mating member **74** when the rotation of the main table **30** is suspended. Further, the meshing assembly **100** disengages the second mating member **76** from the first mating member **74** before starting the rotation of the main table **30**. By this, when the rotation of the main table **30** is suspended, the workpiece **12** is constantly rotated. As a result, a uniform shot peening on the entire surface of the workpiece **12** is achieved. Further, the main table **30** is smoothly rotated when the rotation of the table is started again.

The second mating member **76** is disposed at one end of the rod member **78**. The air cylinder **98** of the meshing assembly **100** drives the rod member **78** in the direction of disengaging the second mating member **76** from the first mating member **74**. Namely, before starting the rotation of the main table **30** by the dividing assembly **42**, the controlling unit **64** contracts the air cylinder **98** by controlling the air-direction regulator **102** based on the information from the dividing assembly **42**. When the air cylinder **98** is contracted (in the direction indicated by the arrow B as in FIG. **8**), the rod member **78** is downwardly swung (in the direction indicated by the arrow A as in FIG. **8**) along with the arm **98**D, the base plate **90**, and the shaft bearings **80**A. At the same time, the pair of brackets **94** fixed to the base plate **90** rotates about the axis of pins **96**. As a result, the second mating member **76**, which is fixed to the end of the rod member **78**, is disengaged from the first mating member **74** (see FIGS. **9**A and **9**B).

When the rotation of the main table **30** is suspended, the controlling unit **64** expands the air cylinder **98** by controlling the air-direction regulator **102** based on the information from the dividing assembly **42**. When the air cylinder **98** expands (the opposite direction to the arrow B), the rod member **78** is upwardly swung (the opposite direction to the arrow A) along with the arm **98**D, the base plate **90**, and the shaft bearings **80**A. At the same time, the pair of brackets **94** fixed to the base plate **90** rotates about the axis of pins **96**. As a result, the second mating member **76**, which is fixed to the end of the rod member **78**, is engaged with the first mating member **74** (see FIGS. **9**A and **9**B).

By this, the engagement and disengagement of the first and second mating members **74**, **76** are conducted with a simple mechanism. Further, since the rotation of the main table **30** and the satellite tables **32** are not interrupted, a uniform shot peening effect on the workpieces **12** is achieved.

As discussed above, the shot-treatment apparatus **10** of this embodiment allows a high throughput of the workpieces **12** with the least possible idle time while achieving a uniform shot peening effect on the workpieces **12**.

Further, as illustrated in FIGS. **7** and **8**, the driving motor **84**, which is located below the pair of the rod members **78**, rotates the second mating member **76** via the chain wheel **86**, the chain **88**, the chain wheel **82**, and the rod member **78**. By this, the size of the shot-treatment apparatus is reduced. Further, the air cylinder **98** is located below the driving motor **84** so that the axis of the air cylinder **98** becomes in parallel with the rotational axis of the motor **84**. By this, the size of the shot-treatment apparatus is reduced further.

In place of the pressure tank **22** and associated facilities thereof as in FIG. **4**, the pressure tank illustrated in FIG. **10** can be used. Below, the pressure tank as in FIG. **10** is briefly described. In FIG. **10**, the elements which are the same as those in FIG. **4** are indicated by the same numerals, and a detailed description is omitted.

As illustrated in FIG. **10**, an upper pressure tank **20**N and lower pressure tank **20**P are connected in series under a constant feeder **20**J. The lower pressure tank **20**P is connected to a cut-gate **20**H. The constant feeder **20**J is connected to the upper pressure tank **20**N via an upper poppet valve **20**Q. The upper pressure tank **20**N is connected to the lower pressure tank **20**P via a lower poppet valve **20**R. The upper poppet valve **20**Q is activated by the pressure from the upper pressure tank **20**N, and the lower poppet valve **20**R is activated by the pressure from the lower pressure tank **20**P.

For projecting shot against a workpiece, the lower pressure tank **20**P is pressurized by closing the lower poppet valve **20**R, and then the cut-gate **20**H below the lower pressure tank **20**P and a flow regulator **20**G are opened to transfer the shot to a mixing valve **20**E (see FIG. **1**). For supplying the shot to the upper pressure tank **20**N while projecting the shot, the upper pressure tank **20**N is depressurized, and then the upper poppet valve **20**Q is opened to transfer a desired amount of shot from a shot tank **20**K (see FIG. **1**) to the upper pressure tank **20**N via the constant feeder **20**J.

When the upper pressure tank **20**N is filled up with the shot, the constant feeder **20**J is closed to pressurize the upper pressure tank **20**N. Then, the upper poppet valve **20**Q is closed by the pressure from the upper pressure tank **20**N. Then, the lower poppet valve **20**R is opened by the pressure difference between the upper pressure tank **20**N and the lower pressure tank **20**P, which is slightly depressurized owing to the projection of the shot. As a result, the shot is transferred to the lower pressure tank **20**P from the upper pressure tank **20**N. After the transferring operation is completed, the pressurization of the upper pressure tank **20**N is terminated, to close the lower poppet valve **20**R.

By this, continuous projection of the shot is allowed.

Second Embodiment

The shot peening apparatus **110** according to the second embodiment of the invention is described below with reference to FIG. **11**. It shows a schematic plan view of the main part of the shot peening apparatus **110** of the second embodiment. The apparatus of this embodiment has the same elements as those of the first embodiment, except for the elements described below. Thus, the elements which are the same as those of the first embodiment are indicated by the same numerals, and a detailed description is omitted.

As in FIG. **11**, on a main table **30**, a plurality of sections (**30**A, **30**B) are formed by a plurality of walls **44** (four walls, in this embodiment) extending in directions from the inside of the table to the circumference. The plurality of sections (**30**A, **30**B) are classified into a first section **30**A, which has at least one satellite table **32**, and a second section **30**B, which does not have the satellite table **32**. The first section **30**A and the second section **30**B are arranged alternately.

The invention of the second embodiment has the same effect as that of the first embodiment. Further, any leakage of the shot from the apparatus is effectively prevented.

With regard to the embodiments disclosed herein, various changes and modifications can be made. For example, the holding member **48** has the rotation-sensing means **66**. Such a configuration is preferable to detect whether a uniform shot peening effect on the workpieces **12** is achieved. However, the rotation-sensing means can be omitted.

The dividing assembly **42** in FIG. **1** rotates the main table **30** about the main shaft **31** in a stepwise manner by a specific angle (90 degrees in this embodiment), which is predetermined based on the arrangement of the satellite tables **32**. Alternatively, a sensor for detecting the satellite table **32** can be used for rotating the main table in a stepwise manner about the main shaft **31** by the specific and predetermined angle based on the positions of the satellite tables **32**.

The meshing assembly **100** as in FIG. **7** includes the rod member **78**. The meshing assembly **100** engages the second mating members **76** with the first mating members **74** when the rotation of the main table **30** is suspended, and disengages the second mating members **76** from the first mating members **74** before starting the rotation of the main table **30**. Such a configuration is preferable for stably rotating the satellite tables **32** and for rotating the main table **30** without any interruption. However, the meshing assembly **100** can be replaced with first and second rubber rollers, which function as the first and second mating members.

In the above embodiments, the meshing assembly **100** includes the air cylinder **98**, which drives the rod member **78** in the direction of disengaging the second mating member **76** from the first mating member **74**. Alternatively, the meshing assembly can be configured using a solenoid in place of the air cylinder **98**, so that the solenoid drives the rod member in the direction of disengaging the second mating member from the first mating member. In another embodiment, the air cylinder **98** can be replaced by a hydraulic cylinder.

The first mating member **74**, which is fixed to the lower end of the driven shaft **33** in the above embodiments, can be integrally formed at the lower end of the driven shaft. Further, the second mating member **76**, which is fixed to one end of the rod member **78** in the above embodiments, can be integrally formed at one end of the rod member.

In the above embodiments, the driving motor **84** for rotating the second mating member **76** is located below the pair of the rod members **78**. Such a configuration is preferable for reducing the size of the apparatus. However, the driving motor for rotating the second mating member can be located in another place, such as on the imaginary extension of the rod member. Alternatively, the driving motor can be a motor equipped with a reducer having a hollow shaft, wherein the hollow shaft of the motor equipped with the reducer is connected to the chain wheel **82**.

In the above embodiments, the air cylinder **98** is disposed below the driving motor **84**, wherein the axis of the air cylinder **98** is in parallel with the rotational axis of the motor **84**. Such a configuration is preferable for reducing the size of the apparatus. However, the cylinder mechanism can be located in another place, such as on the imaginary extension of the rotational axis of the motor **84**.

Although the shot-treatment apparatus discussed in the above embodiments is the shot peening apparatus **10**, **110** having the projecting device **20**, the shot-treatment apparatus can be a shot blasting apparatus having the projecting device **20**. Alternatively, the shot peening apparatus **10**, **110** can be used as a shot peening-curn-shot blasting apparatus.

The embodiments and the modifications thereof discussed above can be combined, if desired.

LIST OF REFERENCE SIGNS

10 shot-peening apparatus (shot-treatment apparatus)
12 workpiece
20 projecting device
30 main table
30A first section
30B second section
32 satellite table
42 dividing assembly
44 wall
46 holding assembly
48 holding member
64 controlling unit
66 rotation-sensing means
74 first mating member
76 second mating member
78 rod member
82 chain wheel (means for transmitting the driving force)
84 driving motor
86 chain wheel (means for transmitting the driving force)
88 chain
98 air cylinder (cylinder mechanism)
100 meshing assembly
110 shot-peening apparatus (shot-treatment apparatus)

The invention claimed is:

1. A shot treatment apparatus comprising:
a projecting device for projecting shot with compressed air through a nozzle against a workpiece;
a rotatable main table located in a place where both a projection area to be projected upon by the shot from the projecting device and a non-projection area other than the projection area are included;
a plurality of rotatable satellite tables mounted on the main table, wherein each of the satellite tables for placing workpieces has a driven shaft in parallel with a main shaft of the main table;
a plurality of first mating members disposed on the individual driven shafts extending downward from each of the satellite tables;
at least one second mating member located below the main table in the projection area, wherein the second mating member is engageable with any of the first mating members to transmit a rotational driving force to the first mating member; and
a meshing assembly for engaging the second mating member with the first mating member when the rotation of the main table is suspended, and for disengaging the second mating member from the first mating member before starting the rotation of the main table;
a holding assembly disposed above the projection area of the main table, wherein the holding assembly holds down the workpiece placed on the satellite table with a holding member which is configured to be rotatable along with the workpiece.

2. The shot-treatment apparatus of claim **1** further comprises a rotation-sensing device for detecting the rotation of the holding member.

3. The shot-treatment apparatus of claim **1** or **2** further comprising:
a driving assembly which rotates the main table about the main shaft in a stepwise manner by a specific angle which is predetermined based on the arrangement of the satellite tables on the main table, so that at least one satellite table is positioned within the projection area when the rotation of the main table is suspended; and
a controlling unit which suspends the projection of the shot from the projecting device while the main table is being rotated by the dividing assembly, and resumes the projection of the shot when the rotation of the main table is suspended.

4. The shot-treatment apparatus of claim **1**,
wherein the meshing assembly further comprises:
a rod member having the second mating member at one end thereof;
and
a cylinder mechanism for driving the rod member in the direction of disengaging the second mating member from the first mating member.

5. The shot-treatment apparatus of claim **4** further comprising a driving motor disposed below the rod member for rotating the second mating member together with the rod member, wherein the rod member is rotated by the motor through a device for transmitting the driving force.

6. The shot-treatment apparatus of claim **5**, wherein the cylinder mechanism is disposed below the driving motor so that the axis of the cylinder mechanism is in parallel with the rotational axis of the motor.

7. The shot-treatment apparatus of claim **6** further comprising at least one first section and at least one second section alternately formed on the main table by a plurality of walls extending from the inside of the table to the circumference thereof, wherein the first section is provided with the satellite table, and the second section has no satellite table.

8. The shot-treatment apparatus of claim **1** further comprising at least one first section and at least one second section alternately formed on the main table by a plurality of walls extending from the inside of the table to the circumference thereof, wherein the first section is provided with the satellite table, and the second section has no satellite table.

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