

DESK-TOP 4-AXIS APPARATUS FOR PROCESSING MIRROR SURFACE

BACKGROUND OF THE INVENTION

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Technical field of the invention

The present invention relates to an ultra-precision processing technology for electronic or optical devices, die parts, etc., and more particularly to a desk-top-type
10 4-axis mirror surface processing apparatus that processes even a hard, brittle material, such as cemented carbide, highly accurately and efficiently into a mirror surface with a complicated shape.

15 Prior art

Desk-top lathe, desk-top milling machine, etc. are used widely to process small parts for home, laboratory, etc. These desk-top processing machines mainly process rather easy-to-process materials such as copper, aluminum,
20 wood, and plastic. On the other hand, to process a refractory material, e.g., a hard, brittle material including fine ceramics, optical glasses, and single semiconductor crystals, used for electronic or optical devices, and cemented carbides etc. for die parts, a large,
25 general-purpose machine must be used conventionally even when the workpiece to be processed is small. Therefore, there has been wide demand to develop a desk-top processing apparatus such as a desk-top lathe that can be used at hand

and can process even a hard, brittle material or a cemented carbide, etc. with high precision and efficiency.

However, the following difficulties were involved in developing a desk-top processing apparatus such as that
5 described above:

(1) To process a hard, brittle material or a cemented carbide etc. to a preferred shape, the workpiece must be moved three-dimensionally (for instance, X, Y, and Z directions) highly accurately. At this time, the workpiece
10 is moved normally in two directions within a horizontal plane (for example, X and Y directions), therefore, a straight travel guide or an NC drive device extends in the X and Y directions, resulting in an excessively large installation area for the desk-top processing apparatus.

15 (2) To avoid this problem, if the workpiece is moved only in one direction within the horizontal plane (for instance, Y direction), and the tool is driven in two directions within the vertical plane (for example, X and Z directions), the straight travel guide for the tool becomes
20 large. In particular, if the tool is mounted on a mounting head supported as a cantilever by the straight travel guide or the NC drive device, to facilitate replacing the tool etc., high-precision processing is disabled because of deflection etc. of the mounting head, caused by a
25 processing resistance. If a hard, brittle material, cemented carbide, etc. is processed, the optimum processing method is to grind with a grindstone, however, processing resistance to grinding is greater than in a normal cutting

process, so a displacement such as deflection of the head becomes still greater.

(3) When a grindstone is used for grinding a workpiece, the tool (grindstone) itself must be rotated to process the workpiece. At this time, if the grindstone can rotate only in one direction (for instance, Z direction), the shape in which the workpiece can be processed is restricted considerably. Consequently, although axes of grindstone revolutions must be provided in two directions (for example, Y and Z directions), the grindstone drive mechanism is complicated and becomes large, so the desk-top processing apparatus becomes bulkier.

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SUMMARY OF THE INVENTION

The present invention aims at solving these problems. That is, an object of the present invention is to provide a desk-top 4-axis apparatus for processing mirror surface in which the deflection etc. of a mounting head for installing a tool is small, the grindstone can rotate in two directions, installation area and apparatus are small and compact, therefore, even a hard, brittle material, cemented carbide, etc. can be processed highly precisely and efficiently.

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The grindstone used for grinding is loaded shortly between grind-grains, therefore, it is difficult to increase its operating efficiency. Meanwhile, to solve

this problem, the inventors of the present invention et al. developed the electrolytic in-process dressing grinding method (abbreviated to ELID grinding method). The present invention is intended to develop a desk-top 4-axis
5 apparatus for processing mirror surface using ELID grinding and reducing processing resistance.

More explicitly, according to the present invention, provided is a desk-top 4-axis apparatus for processing mirror surface composed of a θ table (4) that carries a
10 workpiece (1) to be processed and is driven and rotated by a numeric control system around a vertical B axis, a spindle (6) that is mounted with a conductive grindstone (2) and is driven and rotated around the axis thereof, a grindstone mounting head (8) to which the rotating shaft C
15 of the spindle can be mounted in the Z axis direction parallel to the B axis and in the Y axis direction horizontally orthogonal to the B axis, in a freely detachable manner, a twist prevention guide (10) to prevent the grindstone mounting head from twisting around the X
20 axis and the Z axis, an X · Z table (12) that directly drives the grindstone mounting head using the numeric control system in X and Z axis directions, a Y table (14) that directly drives the θ table using the numeric control system in the Y axis direction horizontally orthogonal to
25 the X-Z plane, and an electrical processing means for electrically processing an electrode and/or the material to be processed.

In this configuration, the workpiece is moved across the horizontal plane only in the Y direction using the Y table (14), and the grindstone is moved in X and Z directions across the vertical plane using the X · Z table (12). Therefore, no protrusion in the X direction is required and the installation area can be made small. In addition, because the twist prevention guide (10) prevents the grindstone mounting head (8) from twisting around X and Z axes, the guide can cooperate with the X · Z table (12) to reduce displacement such as deflection of the grindstone mounting head (8), while guiding the head. Furthermore, since the grindstone mounting head (8) is configured so that the rotating axis C of the spindle (6) can be installed so as to be detachable in Z and Y axis directions, the apparatus can cope with 2-direction grindstone revolutions simply by removing and mounting the head. Therefore, the grindstone drive mechanism can avoid the need of a complicated, large set-up.

According to a preferred embodiment of the present invention, the aforementioned twist prevention guide (10) is composed of a parallel 2-axis rod guide (11a) for guiding the grindstone mounting head (8) in the X axis direction, a double-end supporting block (11b) for supporting both ends of the above-mentioned 2-axis rod guide, and a parallel 2-axis rod guide (11c) for guiding the double-end supporting block in the X axis direction.

Because twisting around X and Z axes is prevented by the twist prevention guide (10) configured simply without a

numeric control mechanism etc., and the X · Z table (12) is numerically controlled in X and Z axis direction, therefore, displacement of the grindstone mounting head can be reduced and X and Z axes can be numerically controlled with high
5 accuracy.

The aforementioned spindle (6) is provided with an X · Z mounting surface (6a) parallel to the X-Z plane and an X · Y mounting surface (6b) parallel to the X-Y plane. The X · Z mounting surface and the X · Y mounting surface
10 are configured to be capable of being mounted to the grindstone mounting head (8) opposite to each other.

In this configuration, by simply mounting the X · Z mounting surface (6a) and the X · Y mounting surface (6b) opposite to each other on the grindstone mounting head (8),
15 the rotating shaft C of the spindle (6) can cope with the rotation of the grindstone in the two directions of the Y and Z axes, while the grindstone drive mechanism can also be made compact.

The above-mentioned means of electrical processing is
20 composed of an electric power supply means (16) to the positive electrode of the grindstone via a rotary feeder and the negative electrode of the aforementioned electrode, and a processing fluid feeding means (18) for supplying a conductive processing fluid between the above-mentioned
25 grindstone and the electrode. The aforementioned electrode is processed either when the workpiece is processed or

intermittently, in the state in which the above-mentioned electrode is or is not in contact with the grindstone.

This configuration can activate either an electrolytic dressing when the electrode is electrolyzed in a contactless mode, or during a discharge truing in a contact mode, so that the electrode can be trued with high accuracy or ELID processed while the workpiece is being processed. Therefore, even a hard, brittle material, cemented carbide, etc., can be processed highly accurately and efficiently.

A numerical control system (20) for numerically controlling θ table, X · Z table and Y table is provided and processes the workpiece using the ELID method to produce a free, curved surface, through simultaneous or successive controlling of the three linear travel axes (X, Y, Z) and one rotation axis (θ).

According to this configuration, a simple numerical control mode is enabled using the numerical control system (20) (for instance, a personal computer), thereby high-accuracy processing can be achieved.

The aforementioned conductive grindstone (2) should be produced by solidifying conductive powder and non-conductive powder by sintering or metal plating. In this configuration, a conductive rotary grindstone can easily be manufactured in any of types of a circular disk, cylinder, ball nose, etc.

The above-mentioned conductive grindstone (2) is a rotating body with bottom surface, outer periphery, and

edge portions. All or part of the portions are used to process the workpiece. The conductive grindstone in this configuration can process the workpiece into a complicated shape while rotating the conductive grindstone.

5 The aforementioned workpiece (1) is composed of a conductive material, which is electrically insulated from the above-mentioned conductive grindstone, and comes into contact with the aforementioned electrode during processing. Thus configured, while avoiding a discharge between the
10 workpiece and the conductive grindstone, the electrode makes contact with the workpiece and can process the workpiece by discharging.

 An AE sensor or a contact detection means is provided to detect a contact between the conductive grindstone (2)
15 and the workpiece (1); with the contact detection means, a voltage is applied across the workpiece made of the aforementioned conductive material and the above-mentioned conductive grindstone, and a potential difference or current variation due to the contact is detected. Thus
20 using the aforementioned contact detection means, the aforementioned electrical processing means is controlled by an ON-OFF operation. Using this configuration, the electrical processing means can be ON-OFF controlled in an interlock with a contact between the conductive grindstone
25 (2) and the workpiece (1).

 Other objects and advantages of the present invention are described below referring to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

5 Fig. 1 is a general isometric view of a desk-top 4-axis apparatus for processing mirror surface according to the present invention.

 Fig. 2 is the front view of the apparatus in Fig. 1.

 Fig. 3 is the left side view of the apparatus in Fig.
10 1.

DESCRIPTION OF PREFERRED EMBODIMENTS

15 Embodiments of the present invention are described below referring to the drawings. In each drawing, identical portions are symbolized using the same numbers, so a duplicate description is omitted here.

 Fig. 1 is a general isometric view of a desk-top 4-axis apparatus for processing mirror surface according to
20 the present invention, and Figs. 2 and 3 are front and left side views thereof, respectively.

 In Figs. 1 to 3, the desk-top 4-axis apparatus for processing mirror surface is provided with a θ table 4, a
25 spindle 6, a grindstone mounting head 8, a twist prevention guide 10, a X · Z table 12, a Y table 14, and an electrical processing means.

 A workpiece 1 to be processed by the desk-top 4-axis

apparatus for processing mirror surface is, for instance, a hard, brittle material such as fine ceramics, optical glass, and semiconductor single crystals used for electronic or optical devices, or a cemented carbide used in die parts etc. The tool for processing this workpiece 1 is a conductive grindstone 2. The conductive grindstone 2 is a rotating body having bottom surface, outer periphery, and edge portions. All or part of these portions grinds the workpiece 1. This conductive grindstone 2 is manufactured by solidifying conductive powder and non-conductive powder by sintering or metal plating. The conductive rotary grindstone 2 can be easily manufactured in the shape of a circular disk, cylinder, ball nose, etc., and while the conductive grindstone 2 is being rotated, the workpiece 1 can be processed into a complicated shape.

The θ table 4 is supported to be able to rotate by cross roller bearings, and is driven and rotated in a numerically controlled mode around the vertical B axis, by means of a pulse motor 4a. The workpiece 1 is mounted on the upper surface of this θ table 4. In this embodiment, the workpiece 1 is made from a conductive material (for example, cemented carbide), and is electrically insulated from the conductive grindstone 2.

The spindle 6 is mounted with the conductive grindstone 2, and is driven and rotated around the axis thereof. The spindle 6 is driven by a power supply of, for instance, AC 100V, 50/60 Hz, thus the conductive grindstone 2 is rotated at a maximum speed of 20,000 rpm.

The spindle 6 is provided with an X · Z mounting surface 6a parallel to the X-Z plane, and an X · Y mounting surface 6b parallel to the X-Y plane. These mounting surfaces 6a, 6b are configured so that the rotating shaft C of the spindle can be detachably mounted in the Z axis direction parallel to the B axis and the Y-axis direction horizontally orthogonal to the B axis.

According to this configuration shown in Figs. 1 to 3, the rotating shaft C of the spindle 6 can be set in the Y-axis direction. Conversely, by simply reversing the X · Z mounting surface 6a and the X · Y mounting surface 6b to each other and mounting the surfaces to the grindstone mounting head 8, the rotating shaft C of the spindle 6 can be set in the Z-axis direction. At this time, the conductive grindstone 2 should preferably be composed of either cylindrical grindstone, cup grindstone, ball nose grindstone, etc. Consequently, the rotating shaft C of the spindle 6 can cope with two directional revolutions; i.e., Y- and Z-axis directions, of the grindstone, together with reducing the size of the grindstone drive mechanism.

The twist prevention guide 10 is composed of a parallel 2-axis rod guide 11a for guiding the grindstone mounting head 8 in the X-axis direction, a double-end supporting block 11b for supporting both ends of this 2-axis rod guide 11a, and a parallel 2-axis rod guide 11c for guiding the double-end supporting block 11b in the Z-axis direction. The double-end supporting block 11b

incorporates a built-in linear bearing that guides the parallel rods of the 2 axes in a straight line, allows the grindstone mounting head 8 to freely move up and down and to left and right with low resistance, and prevents
5 twisting around the X and Z axes.

Using this configuration, the processing resistance acting on the grindstone 2 is borne by 2-axis rod guides 11a, 11b via the grindstone mounting head 8, and the grindstone mounting head 8 can be prevented from twisting
10 around X and Z axes. Because the X · Z table 12 provides a numerical control operation in X- and Z-axis directions, the guide of the X · Z table 12 can be reduced in size while suppressing a displacement of the grindstone mounting head 8 small, therefore, X and Z axes can be numerically
15 controlled with high accuracy.

The X · Z table 12 is guided by a V groove and cross rollers in X- and Y-axis directions. A pulse motor 12a directly drives the grindstone mounting head 8 in the X-axis direction in a numerical control mode. Another pulse
20 motor 12a, not illustrated, directly drives the grindstone mounting head 8 in the X-axis direction. In addition, the Y table 14 is guided in the Y-axis direction also by the V groove and cross rollers, and a pulse motor 14a directly drives the θ table 4 in the Y-axis direction, in a
25 numerical control mode. Otherwise, a numerical control operation can also be carried out using a pulse motor in a feedback control mode with a linear sensor replacing an

open circuit.

Due to this configuration, displacement of the grindstone mounting head 8, such as deflection, can be reduced to a low level. Therefore by means of X · Z table 12 and Y table 14, the workpiece 1 and the tool 2 are moved relative to each other, thus a 3-axis NC control operation can be performed precisely. Furthermore, because the Y table 14 can process the workpiece through a range of the diameter of the θ table by a stroke of the radius thereof. That is, the operating stroke can be reduced to one half, and protrusions of pulse motor 14a etc. can be prevented. Identification number 9 represents a transparent cover showing the entire unit or a partial unit, and covers the desk-top 4-axis apparatus for processing mirror surface, through which anyone can see the interior during operation.

The electrical processing means electrically processes the electrode 22 and/or the workpiece 1. Such an electrical processing operation includes electrolytic dressing and discharge truing. The electrical processing means is composed of a power source means 16 that supplies positive (+) voltage to the grindstone 2 via a rotary feeder (not illustrated), and negative voltage to the electrode 22, and a processing fluid feeding means 18 that supplies a conductive processing fluid between the grindstone 2 and the electrode 22. The electrode 22 should keep a predetermined spacing from the processing surface of the grindstone 2. However, the electrode can also be configured to temporarily come into contact with the

grindstone.

The above-mentioned configuration activates both electrolytic dressing where the electrode 22 is electrolyzed and dressed under a contactless condition, and
5 discharge truing for the electrode 22 temporarily or intermittently to make contact. Therefore, the electrode can be trued with high accuracy and processed by ELID when the workpiece is being processed, so that even a hard, brittle material, cemented carbide etc. can be processed
10 highly accurately and efficiently, so the workpiece can be machined to a mirror surface with a mean roughness Ra of 10 nm or less.

The numerical control device 20 numerically controls θ table 4, X · Z table 12 and Y table 14, and
15 simultaneously or successively controls three straight travel axes X, Y, and Z and one revolutionary axis θ , thereby a free curved surface of the workpiece 1 is processed by ELID.

In addition, the configuration incorporates a contact
20 detection means (not illustrated) having an AE sensor for detecting a contact between the conductive grindstone 2 and the workpiece 1, and using this contact detection means, the electrical processing means is controlled to turn the process ON and OFF, so that interlocked by the contact
25 between the conductive grindstone 2 and the workpiece 1, the electrical processing means is also controlled for ON and OFF.

In the above-mentioned configuration according to the

present invention, the workpiece is moved only in the Y direction across the horizontal plane, and the grindstone is driven in X and Z directions across the vertical plane by the X · Z table 12. Therefore, the installation area of the apparatus can be made small because no protrusion is required in the X direction. In addition, since twisting of the grindstone mounting head 8 around X and Z axes is prevented by the twist prevention guide 10, displacement of the head, such as runout, can be decreased, while guiding the grindstone mounting head 8 in cooperation with the X · Z table 12. Moreover, because the grindstone mounting head 8 is arranged to have the rotating shaft C of the spindle 6 detachably mounted in Z- and Y-axis directions, the head can cope with 2-directional revolutions of the grindstone simply by removing and mounting the grindstone mounting head, hence the grindstone drive mechanism can avoid becoming complicated with a large structure.

Furthermore, because the simply structured twist prevention guide 10 prevents twisting around X and Z axes and the X · Z table 12 performs a numerical control operation in X- and Z-axis directions, displacement of the grindstone mounting head can be reduced while X and Z axes can be numerically controlled highly accurately. In addition, the rotating shaft C of the spindle 6 can cope with revolutions of the grindstone in the two directions of the Y and Z axes by simply reversing X · Z mounting surface 6a and X · Y mounting surface 6b to each other and mounting

them on the grindstone mounting head 8, and the grindstone drive mechanism can be made more compact. In addition, both electrolytic dressing and discharge truing can be adopted; in the former, the electrode is electrolyzed in a contactless manner, and in the latter, the electrode makes contact, as a consequence, the electrode can be either highly precisely trued or ELID processed, while machining the workpiece. Therefore, even a hard, brittle material or cemented carbide can be processed with high accuracy and efficiency.

Hence, the desk-top 4-axis apparatus for processing mirror surface according to the present invention can reduce displacement of the mounting head to which a tool is installed, such as deflection, can cope with two-directional revolutions of the grindstone, can reduce the installation area and can reduce the size of the equipment, thereby can process even a hard, brittle material or cemented carbide with high accuracy and efficiency, which are excellent effects in practice.

Although the present invention has been described referring to several preferred embodiments, the scope of rights included in the present invention should be understood not to be limited only to these embodiments. To the contrary, the scope of rights of the present invention must include all improvements, corrections, and similar entities covered by the scope of the attached claims.

WHAT IS CLAIMED IS

1. A desk-top 4-axis apparatus for processing mirror
5 surface, comprising

a θ table (4) that mounts a workpiece (1) and drives
the workpiece to rotate around the vertical B axis thereof
in a numerical control mode,

a spindle (6) that mounts a conductive grindstone (2)
10 and drives the grindstone to rotate around the axis thereof,

a grindstone mounting head (8) that mounts the
rotating shaft C of the spindle in a detachable manner in
the Z-axis direction parallel to the B-axis and Y-axis
direction horizontally orthogonal to the B axis,

15 a twist prevention guide (10) for preventing the
grindstone mounting head from being twisted around X and Z
axes,

an X • Z table (12) that directly drives the
grindstone mounting head in X- and Z-axis directions in a
20 numerical control mode,

a Y table (14) that directly drives the θ table in
the Y axis direction horizontally orthogonal to the X-Z
plane in a numerical control mode, and

an electrically processing means that electrically
25 processes an electrode and/or the workpiece.

2. The desk-top 4-axis apparatus for processing



mirror surface specified in Claim 1, wherein the said twist prevention guide (10) comprises

a parallel 2-axis rod guide (11a) that guides the grindstone mounting head (8) in the X axis direction,

5 a double-end supporting block (11b) that supports both ends of the said 2-axis rod guide, and

a parallel 2-axis rod guide (11c) that guides the double-end supporting block in the Z-axis direction.

10 3. The desk-top 4-axis apparatus for processing mirror surface specified in Claim 1, wherein the said spindle (6) comprises an X · Z mounting surface (6a) parallel to the X-Z plane and an X · Y mounting surface (6b) parallel to the X-Y plane, in which

15 the X · Z mounting surface and the X · Y mounting surface are disposed in such a manner that both surfaces can be installed to the grindstone mounting head (8) opposite to each other.

20 4. The desk-top 4-axis apparatus for processing mirror surface specified in Claim 1, wherein the said electrically processing means comprises an electric power source means (16) that supplies a positive voltage to the grindstone via a rotating feeder and a negative voltage to
25 the electrode, and

a processing fluid feeding means (18) that feeds a conductive processing fluid between the said grindstone and



electrode, in which

the electrode is processed while the workpiece is being processed by the said electrode either in contact with the grindstone or not in contact therewith, or
5 otherwise intermittently.

5. The desk-top 4-axis apparatus for processing mirror surface specified in Claim 1, comprising a numerical control device (20) that numerically controls the θ table,
10 X • Z table and Y table, wherein

a freely curved surface of the workpiece is processed by an ELID method by simultaneously or successively controlling three straight travel axes (X, Y, and Z) and one revolutional axis (θ).

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6. The desk-top 4-axis apparatus for processing mirror surface specified in Claim 1, wherein the said conductive grindstone (2) is solidified from conductive powder and non-conductive powder by sintering or metal
20 plating.

7. The desk-top 4-axis apparatus for processing mirror surface specified in Claim 1, wherein the said conductive grindstone (2) comprises a rotating body with
25 bottom, outer periphery, and edge portions, in which

the workpiece is processed by all or a part of the said portions.



8. The desk-top 4-axis apparatus for processing mirror surface specified in Claim 1, wherein the said workpiece comprises a conductive material and is insulated
5 electrically from the said conductive grindstone and contacts the said electrode during processing.

9. The desk-top 4-axis apparatus for processing mirror surface specified in Claim 1, comprising an AE
10 sensor for detecting contact between the conductive grindstone (2) and the workpiece (1), or a contact detection means that applies a voltage across the said workpiece comprising a conductive material and the said conductive grindstone and detects a voltage difference or
15 current variation caused by the contact, in which
the said electrical processing means is controlled to turn ON and OFF by the said contact detection means.