



(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 158(3) EPC

(43) Date of publication:
24.01.2007 Bulletin 2007/04

(51) Int Cl.:
B24B 37/04 (2006.01) B24B 21/00 (2006.01)

(21) Application number: **05727544.8**

(86) International application number:
PCT/JP2005/005858

(22) Date of filing: **29.03.2005**

(87) International publication number:
WO 2005/095053 (13.10.2005 Gazette 2005/41)

(84) Designated Contracting States:
DE

(72) Inventor: **YASUI, Heiji**
8620909 (JP)

(30) Priority: **31.03.2004 JP 2004105655**

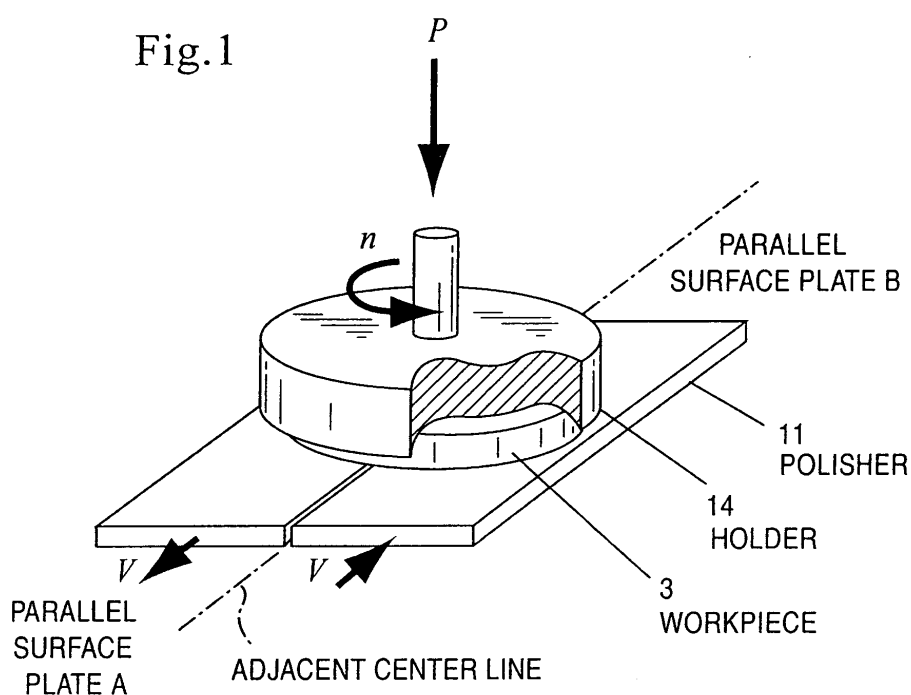
(74) Representative: **Röthinger, Rainer**
c/o Wuesthoff & Wuesthoff
Patent- und Rechtsanwälte
Schweigerstrasse 2
81541 München (DE)

(71) Applicant: **Japan Science and Technology Agency**
Kawaguchi-shi,
Saitama 332-0012 (JP)

(54) **LINEARLY ADVANCING POLISHING METHOD AND APPARATUS**

(57) Continuous feeding of workpieces to an apparatus and effective use of the space around the apparatus are difficult in rotary abrasive finishing. To solve such problems, the present invention provides a conceptually novel method and apparatus for linear abrasive finishing. A pair of parallel flat surface plates adjacent in parallel move linearly in opposite directions. A workpiece is pressed onto both of the surface plates to apply a couple of forces for rotational movement to the workpiece. The

workpiece is subjected to abrasive finishing with abrasive grains by relative movement between the rotation of the workpiece and the linear movement of the pair of surface plates. The workpiece may be held between the pair of parallel flat surface plates and another pair of parallel flat surface plates facing the pair of parallel flat surface plates before one or both surfaces of the workpiece are subjected to the abrasive finishing. Belt polishers passing over a workpiece support may be used instead of the surface plates.



Description

Technical Field

[0001] The present invention relates to abrasive finishing of, for example, metals (steel and nonferrous metals) and nonmetallic materials (ceramic, glass, and plastic).

Background Art

[0002] Abrasive finishing, which is used as a final finishing step in mechanical processing, is growing in importance as device quality has improved recently. Examples of abrasive finishing include lapping, in which a workpiece is rubbed with a lap using an abrasive containing dispersed loose abrasive grains, and polishing, in which a workpiece is polished with a tool softer than metal, called a polisher.

[0003] Abrasive finishing can be performed in various ways, including single-side finishing, double-side finishing, and curved surface finishing. Fig. 10 illustrates a basic way of abrasive finishing. In Fig. 10, a holder 14 holds a workpiece 3 supported by, for example, a carrier 13 and rotates at a speed of n . The workpiece 3 is pressed onto an abrasive surface plate 10 (onto a polisher 11 laminated on the surface plate for polishing) by a pressure of P . The abrasive surface plate 10 is rotated at a speed of N while an abrasive 15 containing loose abrasive grains 12 is supplied to the surface plate 10 (to the polisher 11 for polishing). Relative rotation between the workpiece 3 and the surface plate 10 causes the loose abrasive grains 12 to remove a surface portion of the workpiece 3, thus forming a highly smooth surface. Non-woven fabric or suede-type plastic is often used as the polisher 11. The current maximum speed of the abrasive finishing seems to be about 2 m/s.

Disclosure of Invention

Problems to be Solved by the Invention

[0004] Abrasive finishing using a rotary abrasive surface plate, however, needs the time for attachment/detachment of workpieces because the finishing is generally a batch process in which the abrasive surface plate must be stopped to detach and attach the workpieces. Also, an automated double-side abrasive finishing system capable of continuous feeding of workpieces to the apparatus is difficult to establish. In particular, improving abrasive finishing efficiency is challenging in mass production.

[0005] Furthermore, the rotary abrasive surface plate requires a diameter of at least twice that of a workpiece because the workpiece is processed on the abrasive surface plate. Processing a larger workpiece requires a larger abrasive surface plate and a larger area for installation of the abrasive finishing apparatus. In addition, a rotary abrasive surface plate for double-side abrasive finishing

having a horizontal rotating axis and a vertical plane of rotation is difficult to produce because of the mechanical difficulty of supporting a workpiece. This makes it difficult to sufficiently utilize the space around the apparatus. Accordingly, the development of a conceptually novel method for abrasive finishing has strongly been demanded to facilitate establishment of a more compact automated abrasive finishing system capable of continuous feeding of workpieces to an apparatus and to sufficiently utilize the space around the apparatus.

Means for Solving the Problems

[0006] The present invention provides a conceptually novel method for abrasive finishing which can facilitate establishment of a compact automated abrasive finishing system capable of continuous feeding of workpieces to an apparatus and which allows effective use of the space around the apparatus. Such a system is difficult to establish based on existing methods for rotary abrasive finishing using rotary abrasive surface plates. The present invention also provides an abrasive finishing apparatus based on the novel method.

[0007] That is, the present invention provides a method for linear abrasive finishing which includes pressing a workpiece onto both of a pair of parallel flat surface plates that are adjacent in parallel and move linearly in opposite directions to apply a couple of forces for rotational movement to the workpiece; and subjecting the workpiece to abrasive finishing with abrasive grains by relative movement between the rotation of the workpiece and the linear movement of the pair of flat surface plates. In this method, the workpiece may be held between the pair of parallel flat surface plates and another pair of parallel flat surface plates facing the pair of parallel flat surface plates before one or both surfaces of the workpiece are subjected to the abrasive finishing.

[0008] The present invention further provides a method for linear abrasive finishing which includes pressing a workpiece onto a flat surface plate that moves linearly to apply a couple of forces for rotational movement to the workpiece; and subjecting the workpiece to abrasive finishing with abrasive grains by relative movement between the rotation of the workpiece and the linear movement of the flat surface plate. The flat surface plate has a surface whose friction coefficient differs in a direction perpendicular to a direction in which the flat surface plate moves linearly. In this method, the workpiece may be held between the flat surface plate and another flat surface plate facing the flat surface plate before one or both surfaces of the workpiece are subjected to the abrasive finishing.

[0009] In the above methods, the abrasive finishing can be continuously performed by gradually moving an elongated plate-like carrier having a circular hole holding a circular subcarrier holding the workpiece in one direction as the abrasive finishing progresses.

[0010] In the above methods, additionally, belt polish-

ers passing over a workpiece support may be used instead of the flat surface plates.

[0011] The present invention further provides a linear abrasive finishing apparatus including a pair of parallel flat surface plates adjacent in parallel; means for linearly moving the flat surface plates in opposite directions; and means for pressing a workpiece onto the flat surface plates. This apparatus may further include another pair of parallel flat surface plates disposed opposite the pair of parallel flat surface plates such that the workpiece is held therebetween.

[0012] The above apparatus may further include an elongated plate-like carrier for continuously feeding the workpiece to the abrasive finishing apparatus and ejecting the workpiece therefrom during the abrasive finishing. This apparatus may further include a circular workpiece-holding subcarrier hole in the plate-like carrier, and the center of rotation of the hole may be located on or away from an adjacent center line between the parallel flat surface plates. In addition, the circular subcarrier hole in the plate-like carrier may include a workpiece-holding hole having a shape such as a circle, a square, a rectangle, or a polygon, and the center of rotation thereof may be located on the adjacent center line between the parallel flat surface plates.

[0013] The present invention further provides a linear abrasive finishing apparatus including a flat surface plate that moves linearly and has a surface whose friction coefficient differs in a direction perpendicular to a direction in which the flat surface plate moves linearly; and means for pressing a workpiece onto the flat surface plate. This apparatus may further include another flat surface plate disposed opposite the flat surface plate such that the workpiece is held therebetween.

[0014] Each of the above apparatuses may include a workpiece support and a pair of belt polishers passing over the workpiece support instead of the flat surface plates.

[0015] The methods according to the present invention leave no unidirectional abrasive streaks because the abrasive finishing is performed by rotating a workpiece using a couple of forces produced by the linear movement of the flat surface plates. These methods can therefore provide an excellent nondirectional finished surface with a roughness of about 1.5 nm or less (intervals of several atoms or less). Without rotation, the workpiece would suffer streaks oriented in the direction in which the flat surface plates move, leading to a roughness exceeding 10 nm. The methods according to the present invention can thus provide an ultrasmooth surface without such abrasive streaks.

Advantages

[0016] The methods for linear abrasive finishing according to the present invention have the following advantages:

1) An abrasive finishing apparatus that is more space-saving than rotary abrasive finishing apparatuses can be produced.

2) An automated abrasive finishing system capable of continuous feeding of workpieces to the apparatus can be established. Such a system is difficult to establish based on known methods for abrasive finishing using rotary abrasive surface plates.

3) An automated vertical double-side abrasive finishing system with a vertical plane of rotation can be produced to effectively utilize the space around the apparatus.

Best Mode for Carrying Out the Invention

[0017] The mechanism of a method for linear abrasive finishing according to the present invention will now be described with reference to Fig. 1, which illustrates an example of polishing. The method for polishing according to the present invention involves the use of a pair of polishers 11 adjacent in parallel as parallel flat surface plates A and B. The pair of polishers 11 move linearly at a speed of V in opposite directions on both sides of an adjacent center line. A workpiece 3 is held by a holder 14 that can rotate without substantial restriction. The workpiece 3 is brought into contact with both of the pair of polishers 11 and is pressed by a pressure of P to apply a couple of forces for rotational movement to the workpiece 3. An abrasive liquid containing loose abrasive grains is supplied to surfaces of the polishers 11. Relative movement between the rotation of the workpiece 3 and the linear movement of the polishers 11 causes the loose abrasive grains to remove a surface portion of the workpiece 3, thus forming a highly smooth surface.

[0018] In the method according to the present invention, the rotation of a workpiece depends basically on the movement direction and surface structure of plates or polishers. The workpiece may also be rotated using a driving force generated by, for example, a motor to control the relative movement between the workpiece and the plates or polishers for abrasive finishing. An abrasive finishing apparatus based on the method can perform abrasive finishing if the total width of the pair of polishers 11 is slightly larger than the diameter of the workpiece 3. The pair of polishers 11 thus occupy a smaller space than a rotary abrasive surface plate.

[0019] For double-side polishing using this method, as shown in Fig. 2, the workpiece 3 is held between two pairs of parallel surface polishers 11 that move linearly in opposite directions at a speed of V. These polishers 11 are pressed onto the top and bottom of the workpiece 3 by a pressure of P using a workpiece support (not shown) formed of, for example, metal or ceramic. Surfaces of the polishers 11 are brought into contact with surfaces of the workpiece 3 to apply a couple of forces for rotational movement to the workpiece 3. An abrasive liquid containing loose abrasive grains is supplied to the surfaces of the polishers 11 to remove top and bottom

surface portions of the workpiece 3 with the loose abrasive grains, thus forming highly smooth surfaces. Belt polishers may be used as the polishers 11 so that they can continuously pass through a polishing position.

[0020] Referring to Fig. 3, continuous double-side abrasive finishing can be automatically performed in the method shown in Fig. 2 by gradually moving an elongated plate-like carrier 13 having a circular workpiece-holding hole holding the workpiece 3 in either direction as the abrasive finishing progresses. The method shown in Fig. 3, which is applied to horizontal double-side abrasive finishing with the plane of rotation oriented horizontally, can also be easily applied to vertical double-side abrasive finishing with the plane of rotation oriented vertically. Such a vertical double-side abrasive finishing system allows effective use of the space around the apparatus.

[0021] The method for abrasive finishing shown in Figs. 1 to 3 can be used for workpieces having a central hole, such as magnetic disc substrates, if the workpiece-holding hole of the carrier 13 is disposed on the adjacent center line between the pair of parallel flat surface plates. For workpieces having no central hole, such as silicon wafers, however, the central portions thereof cannot be subjected to abrasive finishing because these portions do not come into contact with the polishers. Referring to Fig. 4, a subcarrier 13A having a circular hole may be provided in the plate-like carrier 13 to allow abrasive finishing of the entire surfaces of the workpiece 3. The center of rotation of the hole is located away from the adjacent center line between the pair of parallel flat surface plates A and B.

[0022] The hole of the subcarrier 13A may be formed in another shape such as a square, a rectangle, or a polygon to perform abrasive finishing. For abrasive finishing of a circular workpiece having no hole, the center of the workpiece hole in the carrier 13 may be located away from the adjacent center line to allow abrasive finishing of the entire surfaces of the workpiece 3 without using the subcarrier 13A.

[0023] Referring to Fig. 5, the subcarrier 13A may have two or more workpiece-holding holes disposed away from the center of rotation of the subcarrier 13A so as to surround the center of rotation. This subcarrier 13A allows abrasive finishing of the entire surfaces of workpieces 3 irrespective of whether the workpieces 3 have a hole or not. This method is suitable for abrasive finishing of a large number of workpieces.

[0024] Figs. 6 and 7 are schematic diagrams illustrating methods and apparatuses for abrasive finishing according to other embodiments of the present invention. Linearly moving plates are used, each having a surface whose friction force differs in a direction perpendicular to the direction in which the plates move linearly. The linearly moving plates can be pressed onto a workpiece to apply a couple of forces for rotational movement to the workpiece.

[0025] These abrasive finishing methods can be used for single-side or double-side polishing. Referring to Fig.

6, a workpiece 3 held by a carrier 13 is placed between belt polishers 11, as a pair of top and bottom flat surface plates, which move linearly in opposite directions at a speed of V. The polishers 11 are pressed onto the top and bottom of the workpiece 3 by a pressure of P so that surfaces of the polishers 11 are brought into contact with surfaces of the workpiece 3 to perform polishing.

[0026] Each polisher has different surface conditions on both sides of a longitudinal center line to produce different frictional forces. For example, the surface of the polisher may have circular holes or linear grooves on either side of the longitudinal center line to reduce the contact area between the polisher and the workpiece on the side. As a result, a smaller frictional force can be produced than on the other side. Different frictional forces can also be produced on both sides of the longitudinal center line to apply a couple of forces by changing the mechanical properties of the polisher, such as surface hardness, to create different contact conditions between the workpiece and the polisher on both sides.

[0027] A couple of forces for rotational movement is thus applied to the workpiece 3. An abrasive liquid containing loose abrasive grains is supplied to the surfaces of the polishers 11. Relative movement between the rotation of the workpiece 3 and the linear movement of the polishers 11 causes the loose abrasive grains to remove top and bottom surface portions of the workpiece 3, thus forming highly smooth surfaces. In this method, as shown in Fig. 7, the belt polishers 11 may also be linearly moved in the same direction at a speed of V to perform abrasive finishing.

[0028] A workpiece is held between linearly moving flat surface plates facing each other to perform single-side or double-side abrasive finishing in the embodiments shown in Figs. 6 and 7, although a single polisher that moves linearly at a speed of V may also be used. The workpiece may be pressed onto the single polisher to apply a couple of forces for rotational movement to the workpiece. Abrasive finishing can be performed by relative movement between the rotation of the workpiece and the linear movement of the polisher.

EXAMPLE 1

[0029] An example of a method according to the present invention will be described below with reference to Fig. 8.

[0030] In Fig. 8, a pair of adjacent belt polishers A and B were moved linearly and rotated by motors M1 and M2, respectively, in opposite directions so as to pass over a workpiece support. A circular magnetic disc substrate, as a workpiece, was polished by pressing it onto surfaces of the pair of belt polishers A and B on both sides of the adjacent center line therebetween. Alumina abrasive grains were uniformly supplied to the polishers. The substrate was pressed by a pressure of 3.7 kPa. The polishers used were of suede type and were moved at a speed of 1.5 m/s. The magnetic disc substrate was of aluminum

type and was polished for five minutes. The resulting couple of forces rotated the magnetic disc substrate at a speed of at least 0.15 m/s. Relative movement between the substrate and the polishers A and B caused the abrasive grains to polish the substrate, thus forming a smooth surface.

[0031] Fig. 9 shows the surface smoothness of the polished magnetic disc substrate according to three-dimensional roughness measurements using a high-precision interferometric surface profiler (WYKO). The magnetic disc substrate had a significantly smoothly polished surface with a roughness of about 1.3 nm in terms of Ra, which can be determined as an ultrasmooth surface. These results demonstrate the effectiveness of the linear abrasive finishing apparatus according to the present invention.

Brief Description of the Drawings

[0032]

Fig. 1 is a schematic diagram illustrating the mechanism of a method for linear abrasive finishing according to the present invention.

Fig. 2 is a schematic diagram illustrating a method for linear double-side abrasive finishing according to an embodiment of the present invention.

Fig. 3 is a schematic diagram illustrating an automatic continuous process using a linear double-side abrasive finishing apparatus according to the present invention.

Fig. 4 is a schematic diagram illustrating a modification of the automatic continuous process shown in Fig. 3.

Fig. 5 is a schematic diagram illustrating another modification of the automatic continuous process shown in Fig. 3.

Fig. 6 is a schematic diagram illustrating a method for linear double-side abrasive finishing according to another embodiment of the present invention.

Fig. 7 is a schematic diagram illustrating a modification of the method for linear double-side abrasive finishing shown in Fig. 6.

Fig. 8 is a perspective view of a linear abrasive finishing apparatus used in an example.

Fig. 9 is a photograph showing the surface smoothness of a magnetic disc substrate subjected to abrasive finishing in the example according to three-dimensional roughness measurements using a high-precision interferometric surface profiler (WYKO).

Fig. 10 is a schematic diagram illustrating an example of a known mechanism of abrasive finishing (polishing). Reference Numerals

- 3 workpiece
- 10 surface plate
- 11 polisher
- 12 loose abrasive grains

- 13 carrier
- 14 holder
- 15 abrasive liquid

Claims

1. A method for linear abrasive finishing, comprising pressing a workpiece onto both of a pair of parallel flat surface plates that are adjacent in parallel and move linearly in opposite directions to apply a couple of forces for rotational movement to the workpiece; and subjecting the workpiece to abrasive finishing with abrasive grains by relative movement between the rotation of the workpiece and the linear movement of the pair of flat surface plates.
2. The method for linear abrasive finishing according to Claim 1, wherein the workpiece is held between the pair of parallel flat surface plates and another pair of parallel flat surface plates facing the pair of parallel flat surface plates before one or both surfaces of the workpiece are subjected to the abrasive finishing.
3. A method for linear abrasive finishing, comprising pressing a workpiece onto a flat surface plate that moves linearly to apply a couple of forces for rotational movement to the workpiece, the flat surface plate having a surface whose friction coefficient differs in a direction perpendicular to a direction in which the flat surface plate moves linearly; and subjecting the workpiece to abrasive finishing with abrasive grains by relative movement between the rotation of the workpiece and the linear movement of the flat surface plate.
4. The method for linear abrasive finishing according to Claim 3, wherein the workpiece is held between the flat surface plate and another flat surface plate facing the flat surface plate before one or both surfaces of the workpiece are subjected to the abrasive finishing.
5. The method for linear abrasive finishing according to any of Claims 1 to 4, wherein the abrasive finishing is continuously performed by gradually moving an elongated plate-like carrier having a circular hole holding a circular subcarrier holding the workpiece in one direction as the abrasive finishing progresses.
6. The method for linear abrasive finishing according to any of Claims 1 to 5, wherein belt polishers passing over a workpiece support are used instead of the flat surface plates.
7. A linear abrasive finishing apparatus comprising a pair of parallel flat surface plates adjacent in parallel;

means for linearly moving the flat surface plates in opposite directions; and means for pressing a workpiece onto the flat surface plates.

8. The linear abrasive finishing apparatus according to Claim 7, further comprising another pair of parallel flat surface plates disposed opposite the pair of parallel flat surface plates such that the workpiece is held therebetween. 5
9. The linear abrasive finishing apparatus according to Claim 8, further comprising an elongated plate-like carrier for continuously feeding the workpiece to the abrasive finishing apparatus and ejecting the workpiece therefrom during the abrasive finishing. 10
10. The linear abrasive finishing apparatus according to Claim 9, further comprising a circular workpiece-holding subcarrier hole in the plate-like carrier, the center of rotation of the hole being located on or away from an adjacent center line between the parallel flat surface plates. 15
11. The linear abrasive finishing apparatus according to Claim 10, wherein the circular subcarrier hole in the plate-like carrier includes a workpiece-holding hole having a shape such as a circle, a square, a rectangle, or a polygon, the center of rotation thereof being located on the adjacent center line between the parallel flat surface plates. 20
12. A linear abrasive finishing apparatus comprising a flat surface plate that moves linearly and has a surface whose friction coefficient differs in a direction perpendicular to a direction in which the flat surface plate moves linearly; and means for pressing a workpiece onto the flat surface plate. 25
13. The linear abrasive finishing apparatus according to Claim 12, further comprising another flat surface plate disposed opposite the flat surface plate such that the workpiece is held therebetween. 30
14. The linear abrasive finishing apparatus according to any of Claims 7 to 13, comprising a workpiece support and a pair of belt polishers passing over the workpiece support instead of the flat surface plates. 35

Amended claims under Art. 19.1 PCT 40

1. (Original): A method for linear abrasive finishing, comprising pressing a workpiece onto both of a pair of parallel flat surface plates that are adjacent in parallel and move linearly in opposite directions to apply a couple of forces for rotational movement to the workpiece; and subjecting the workpiece to abrasive finishing with abrasive grains by relative movement 45

between the rotation of the workpiece and the linear movement of the pair of flat surface plates.

2. (Original): The method for linear abrasive finishing according to Claim 1, wherein the workpiece is held between the pair of parallel flat surface plates and another pair of parallel flat surface plates facing the pair of parallel flat surface plates before one or both surfaces of the workpiece are subjected to the abrasive finishing.

3. (Original): A method for linear abrasive finishing, comprising pressing a workpiece onto a flat surface plate that moves linearly to apply a couple of forces for rotational movement to the workpiece, the flat surface plate having a surface whose friction coefficient differs in a direction perpendicular to a direction in which the flat surface plate moves linearly; and subjecting the workpiece to abrasive finishing with abrasive grains by relative movement between the rotation of the workpiece and the linear movement of the flat surface plate.

4. (Original): The method for linear abrasive finishing according to Claim 3, wherein the workpiece is held between the flat surface plate and another flat surface plate facing the flat surface plate before one or both surfaces of the workpiece are subjected to the abrasive finishing.

5. (Original): The method for linear abrasive finishing according to any of Claims 1 to 4, wherein the abrasive finishing is continuously performed by gradually moving an elongated plate-like carrier having a circular hole holding a circular subcarrier holding the workpiece in one direction as the abrasive finishing progresses.

6. (Original): The method for linear abrasive finishing according to any of Claims 1 to 5, wherein belt polishers passing over a workpiece support are used instead of the flat surface plates.

7. (Currently amended): A linear abrasive finishing apparatus utilized in the method according to claim 1, comprising a pair of parallel flat surface plates adjacent in parallel; means for linearly moving the flat surface plates in opposite directions; and means for pressing a workpiece onto the flat surface plates.

8. (Original): The linear abrasive finishing apparatus according to Claim 7, further comprising another pair of parallel flat surface plates disposed opposite the pair of parallel flat surface plates such that the workpiece is held therebetween.

9. (Original): The linear abrasive finishing apparatus according to Claim 8, further comprising an elongat-

ed plate-like carrier for continuously feeding the workpiece to the abrasive finishing apparatus and ejecting the workpiece therefrom during the abrasive finishing.

5

10. (Original): The linear abrasive finishing apparatus according to Claim 9, further comprising a circular workpiece-holding subcarrier hole in the plate-like carrier, the center of rotation of the hole being located on or away from an adjacent center line between the parallel flat surface plates.

10

11. (Original): The linear abrasive finishing apparatus according to Claim 10, wherein the circular subcarrier hole in the plate-like carrier includes a workpiece-holding hole having a shape such as a circle, a square, a rectangle, or a polygon, the center of rotation thereof being located on the adjacent center line between the parallel flat surface plates.

15

20

12. (Original): A linear abrasive finishing apparatus comprising a flat surface plate that moves linearly and has a surface whose friction coefficient differs in a direction perpendicular to a direction in which the flat surface plate moves linearly; and means for pressing a workpiece onto the flat surface plate.

25

13. (Original): The linear abrasive finishing apparatus according to Claim 12, further comprising another flat surface plate disposed opposite the flat surface plate such that the workpiece is held therebetween.

30

14. (Original): The linear abrasive finishing apparatus according to any of Claims 7 to 13, comprising a workpiece support and a pair of belt polishers passing over the workpiece support instead of the flat surface plates.

35

Statement under Art. 19.1 PCT

40

Claim 7 has been amended to clarify that the apparatus is used for the method according to claim 1.

The cited reference does not disclose such an abrasive finishing apparatus for particular abrasive finishing method.

45

50

55

Fig.1

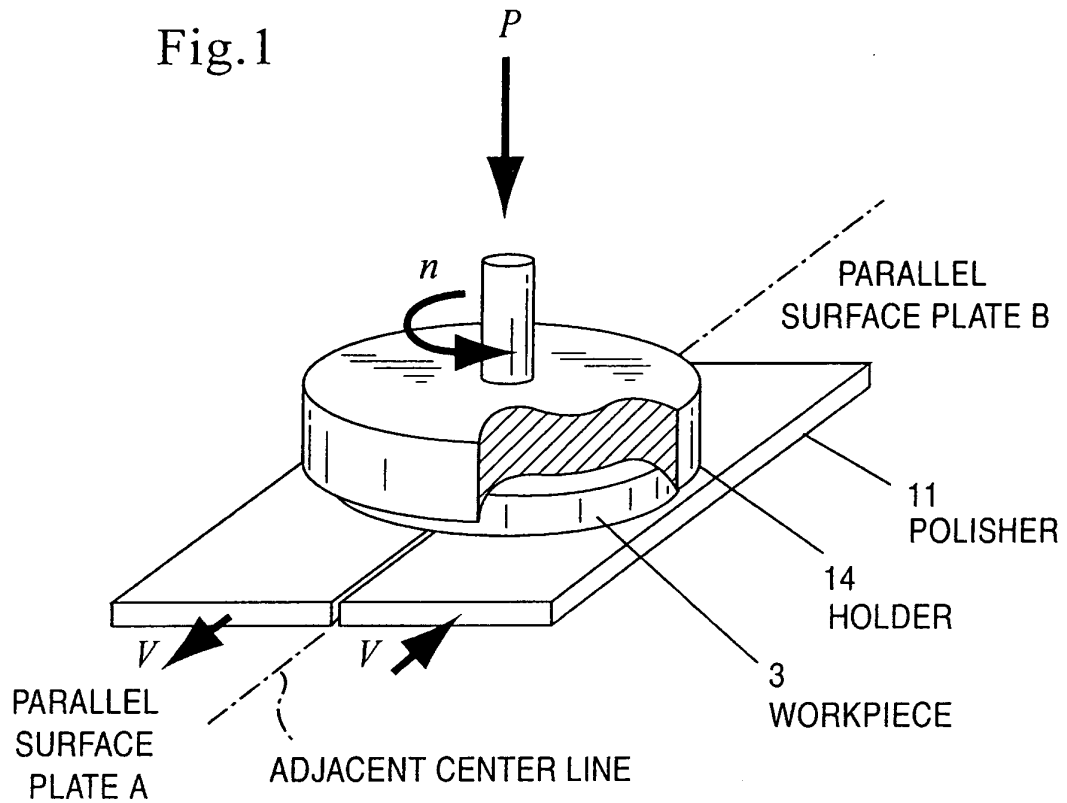


Fig.2

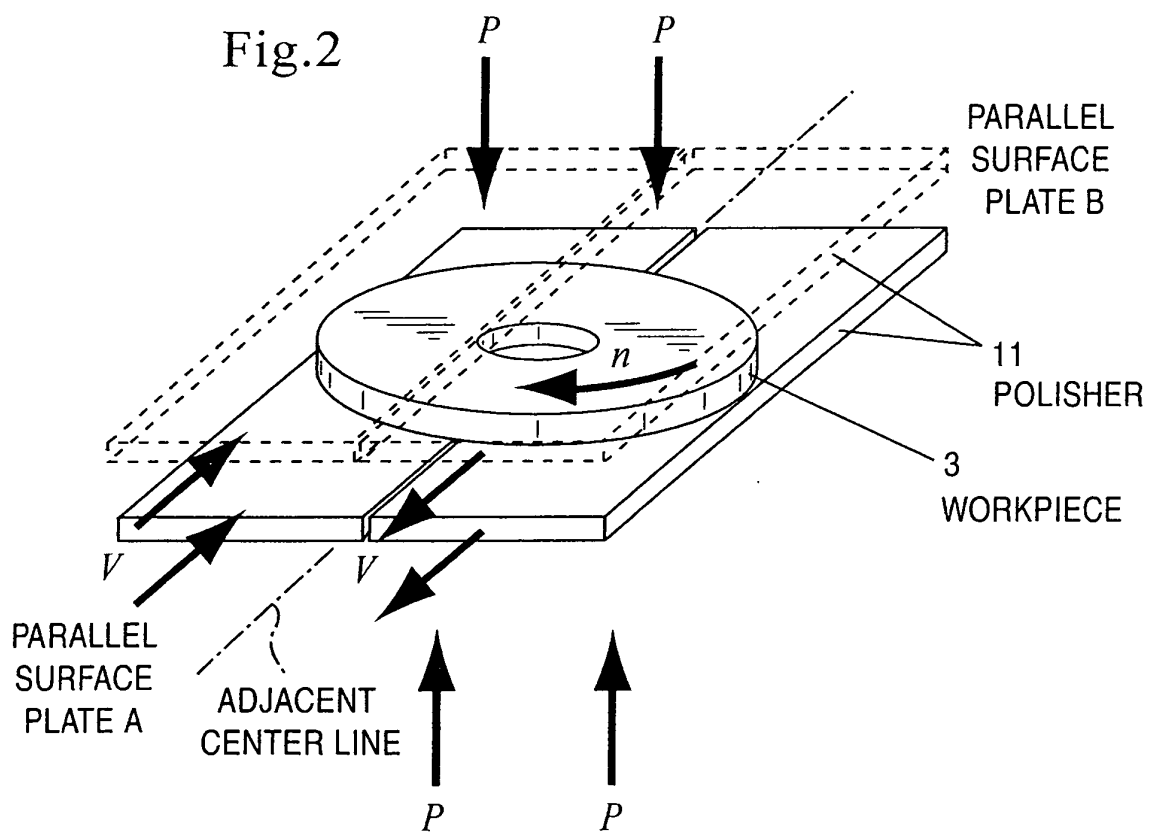


Fig.3

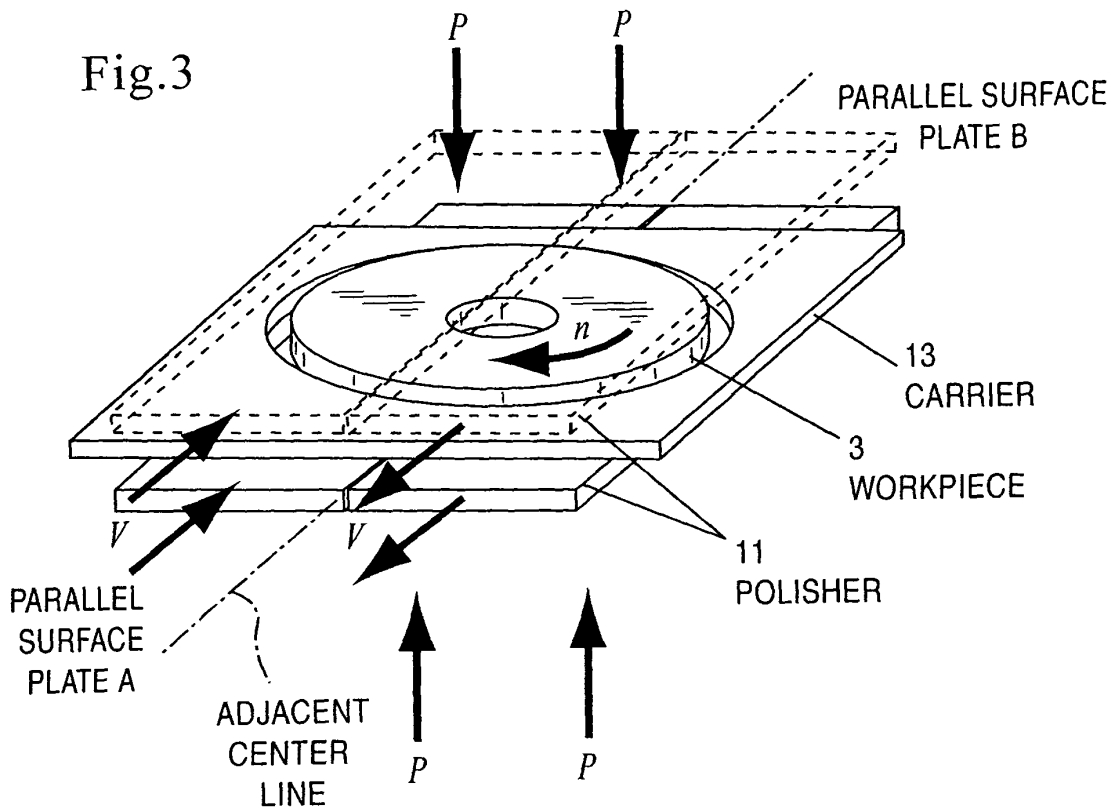


Fig.4

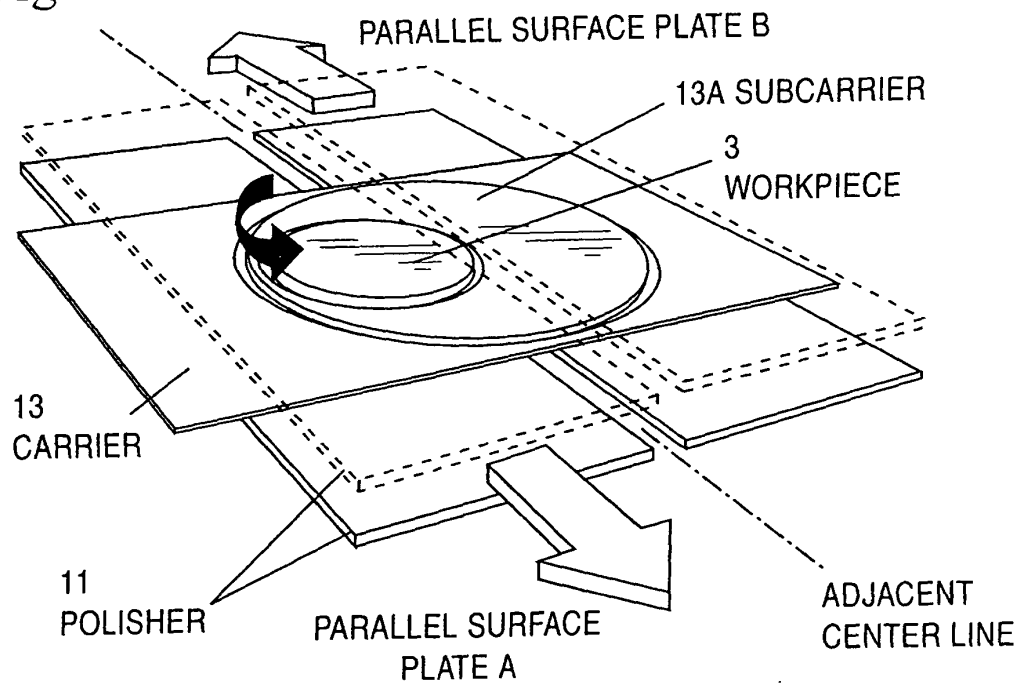


Fig.5

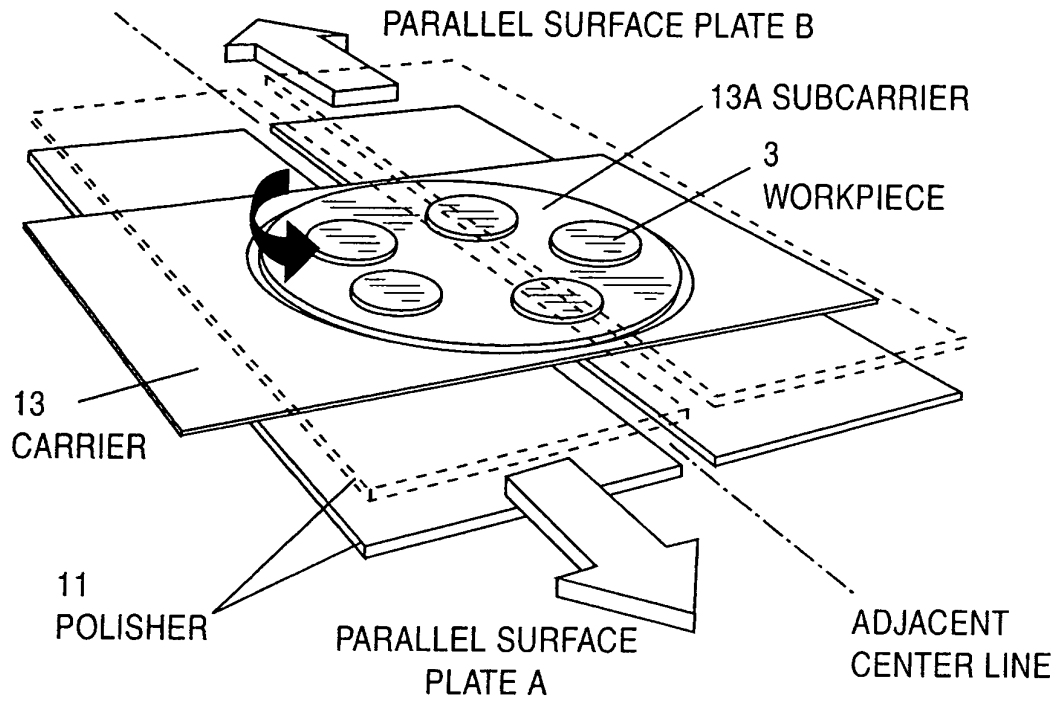


Fig.6

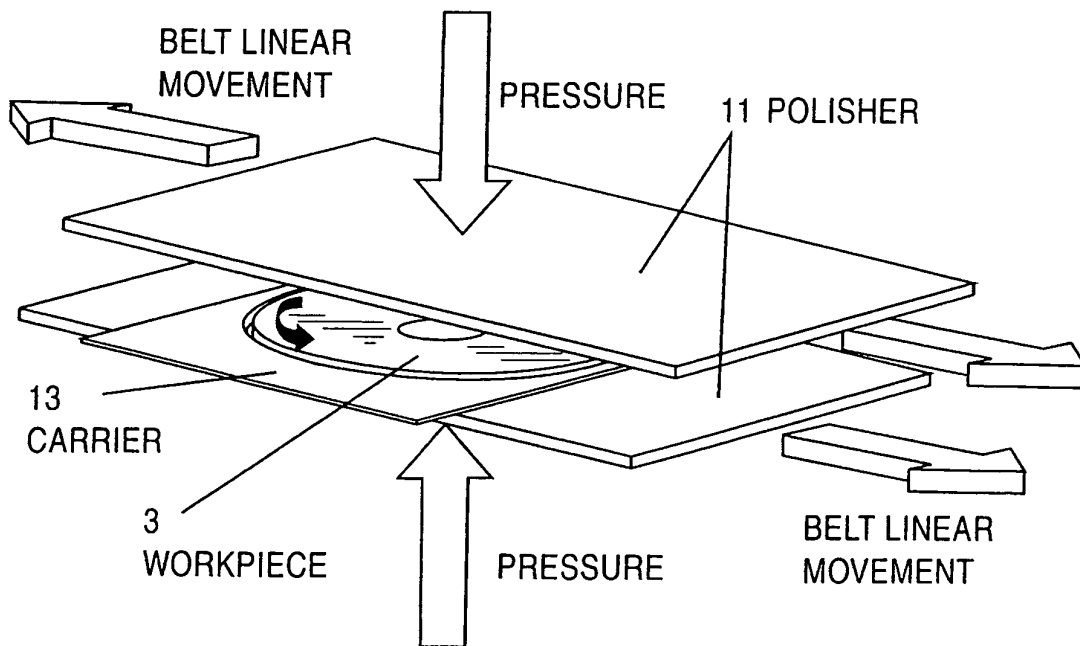


Fig.7

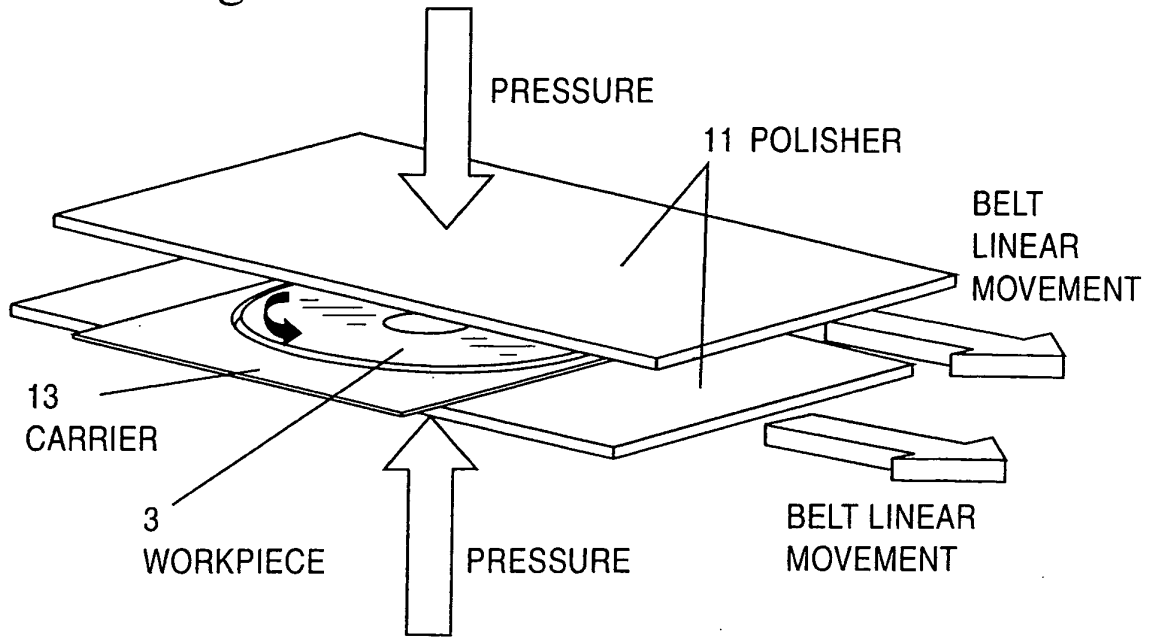


Fig.8

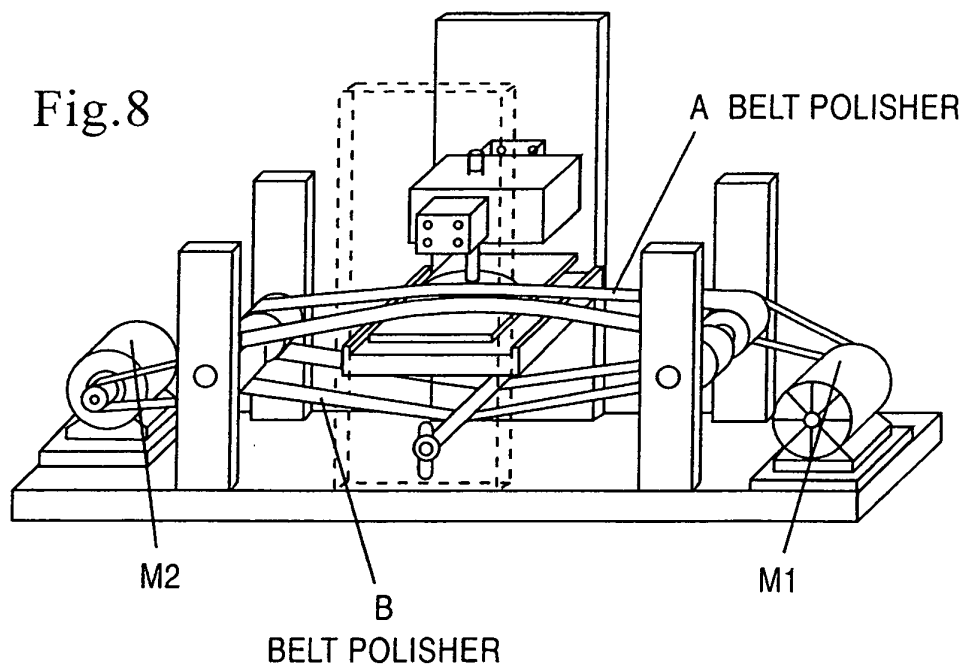


Fig. 9

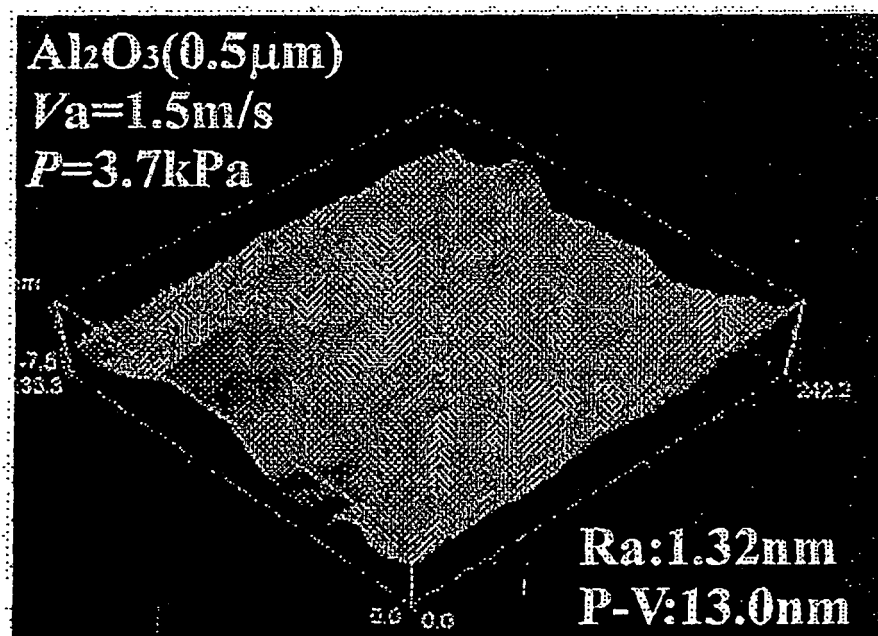
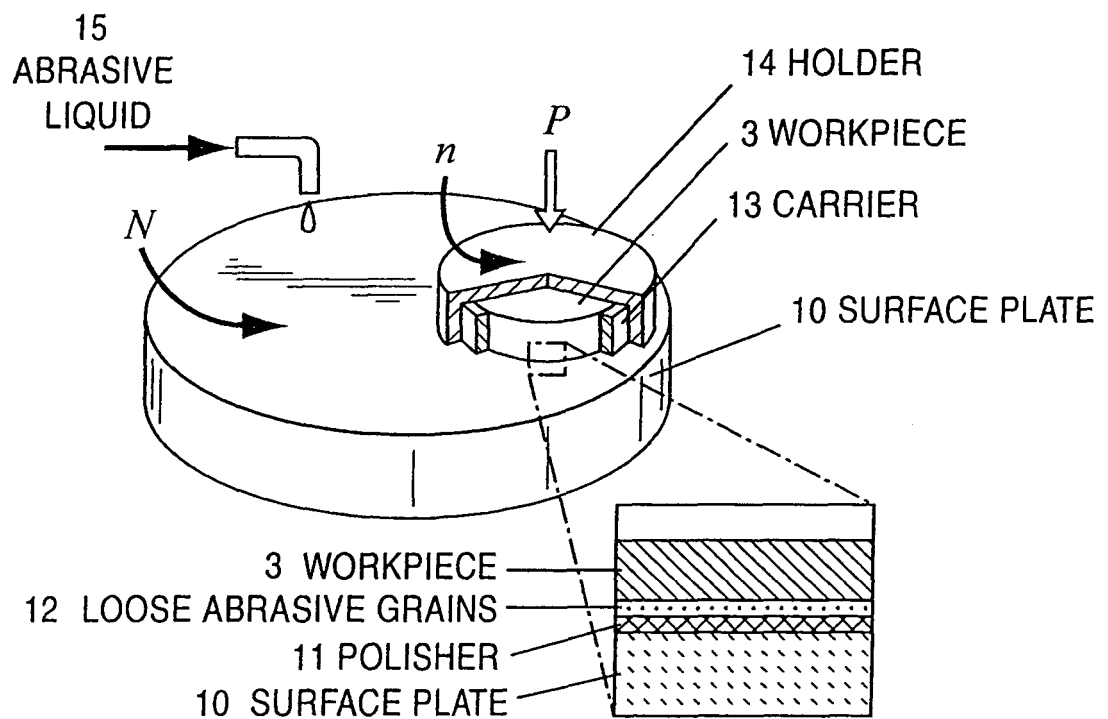


Fig. 10



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2005/005858

A. CLASSIFICATION OF SUBJECT MATTER Int.Cl. ⁷ B24B37/04, 21/00		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols) Int.Cl. ⁷ B24B37/04, 21/00, H01L21/304		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2005 Kokai Jitsuyo Shinan Koho 1971-2005 Toroku Jitsuyo Shinan Koho 1994-2005		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y A	JP 8-052652 A (ONTRAK SYSTEMS, INC.), 27 February, 1996 (27.02.96), Par. No. [0023]; Fig. 10 & EP 696495 A1	7 8-11 1-6, 12-14
X Y A	JP 8-195364 A (ONTRAK SYSTEMS, INC.), 30 July, 1996 (30.07.96), Par. No. [0005]; Fig. 1 & EP 706856 A1 & EP 919330 A1	7 8-11 1-6, 12-14
Y A	JP 60-080559 A (Mitsubishi Metal Corp.), 08 May, 1985 (08.05.85), Claims; Figs. 2A, 2B (Family: none)	8 2, 4, 13
☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 28 June, 2005 (28.06.05)		Date of mailing of the international search report 12 July, 2005 (12.07.05)
Name and mailing address of the ISA/ Japanese Patent Office		Authorized officer
Facsimile No.		Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2005/005858

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 10-249720 A (Kobe Steel, Ltd.), 22 September, 1998 (22.09.98), Claims; Fig. 1a (Family: none)	9-11 5

Form PCT/ISA/210 (continuation of second sheet) (January 2004)