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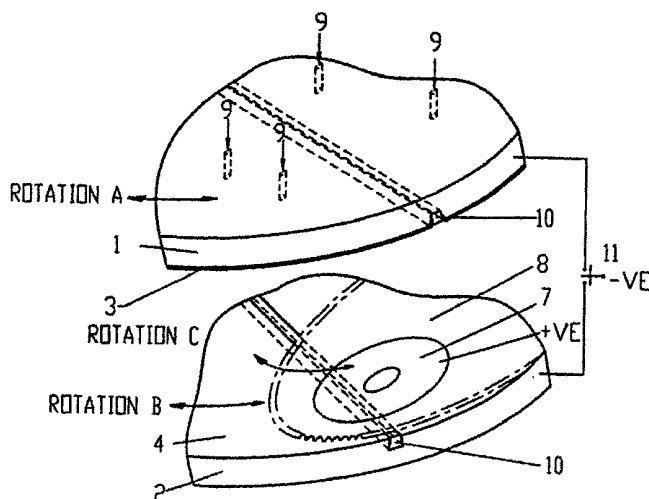
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(54) Title: COMBINED ELECTROLYTIC POLISHING AND ABRASIVE SUPER-FINISHING PROCESS



(57) Abstract: A combined process of electrolytic polishing and abrasive super-finishing of metal surface, provides a method of super-finishing that yield a uniform and smoother finish of as low as less than 7 Å, more planar and atomically cleaner finish and at a higher process efficiency. The workpiece (7, 7a) is sandwiched between two polishing pads (3, 4) or texturing pads (14, 15); the workpiece (7, 7a) is connected to the anode; the cathodes (10, 10a) are located in the radial slots in the finishing wheels (1, 2, 12, 13); the electrolytic solution (9, 9a) is continuously supplied to the finishing wheel surface and filled the cathode gaps between the cathode and workpiece surface, thus allowing a current to flow through the metallic surface of the workpiece to the cathode and, thereby, conducts electrolytic polishing in conjunction with abrasive super-finishing. A switch (11), at the cathode side, controls the current flow from side to side of the workpiece periodically to ensure uniform processing on both sides of the workpiece.



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Combined Electrolytic Polishing and Abrasive Super-finishing Process

FIELD OF THE INVENTION

This invention relates to a combined process of electrolytic polishing and mechanical abrasive super-finishing of metallic surfaces.

BACKGROUND OF THE INVENTION

Surface finishing operation can be done with free abrasive or fixed abrasive; with free abrasive, very fine surface finish with little or no scratches can be produced but the stock removal rate is low; with fixed abrasive, such as abrasive bonded on flexible backing material or bonded as a rigid block, coarser surface finish can be produced but there may be scratches and the stock removal rate is high. Such surface finishing operations are used in various industry, for example, in the polishing/texturing of computer disk substrates, polishing of stainless steel sheets for decoration, grinding of automotive brake and clutch disks, honing of pipes and piston bores and so on, where quality surface finish is desired.

A thin-film memory disk has a thin layer of magnetic layer sputtered on both sides of a specially polished and textured substrate, which may be made of nickel-phosphorus plated aluminium. The surfaces of such substrate must be highly polished to ensure the required flatness and, thereafter, textured. Texturing is necessary both to reduce the stiction problem of the read-write head on the memory disk and to improve on the magnetics of the recording layer. These polishing and texturing processes normally employ free-abrasive. A well polished and well textured substrate will ensure head flying stability, low flying height and reliable disk operation.

Polishing leaves random process marks on the disk substrates, but texturing removes the polishing marks but leaves basically concentric process marks. Prior art describes both polishing and texturing for single disk processing, such as in publications

WO98/28101 and WO99/10569, the latter is a derivative of Japan application 9-226923, and are pioneered by Unique Technology International Private Limited.

In other applications where surface finish is not as stringent as in computer disk, surface finishing process normally employ fixed-abrasive, with the advantage of faster stock removal.

OBJECT OF THE INVENTION

The primary object of this invention is to produce good quality surface finish on metallic surfaces using a combined process of electrolytic polishing and mechanical abrasive finishing.

The second object of this invention is to ensure that both sides of the finished surfaces of each workpiece in double-side surface finishing are equally uniform in substance.

The third object of this invention is to improve both the process efficiency and process time in surface finishing of metallic surfaces.

Other objects, features and advantages of the present invention will become apparent from the detailed description which follows, or may be learned by practice of the invention.

SUMMARY OF THE INVENTION

This invention provides a combined process of electrolytic polishing and abrasive surface finishing of both planar and cylindrical metallic surface. The workpieces are sandwiched between two finishing wheels with an adjustable normal pressure, pushed across the finishing surfaces by means of metal carriers, the surfaces of the carriers being covered with an electrical insulator; the workpieces are being connected to the anode of the power supply through the metal carriers, inner and/or outer rings; the

cathode bars are being located in radial slots on the finishing wheels and maintain a small but consistent cathode gap of less than one millimeter with the workpiece surface; the electrolytic solution is being continuously supplied to the surface of the finishing wheels and filled the cathode gap and, thereby, completing the electric circuit and allowing a current to flow through the surface of the workpiece to the cathode and conduct electrolytic polishing, combined with the mechanical abrasive finishing of the workpiece surface.

To texture a polished workpiece, a singular workpiece is sandwiched between two finishing wheels, rotated relative to the finishing wheel surfaces; the workpiece is connected to the anode of a power supply via the workpiece clamp, while the finishing wheels are connected to the cathode; the cathode bars are being located in the radial slots on the finishing wheels and maintaining small but consistent cathode gap of less than one millimeter with the workpiece surfaces; the electrolytic solution is being continuously supplied to the surface of the finishing wheels and filled the cathode gap and, thereby, completing the electric circuit and allowing a current to flow through the surface of the workpiece to the cathodes and conduct electrolytic polishing combined with the abrasive texturing of the workpiece;

The finishing wheel mentioned above is metallic and on the working side may be disposed either a porous polishing pad or an abrasive pad by means of pressure-sensitive adhesive, or it may be bonded a plurality of rigid abrasive blocks, depending on the roughness of the surface finish desired. For super-finishing, porous polishing pad may be used with the electrolytic solution containing fine suspended abrasives. The polishing pad at the cathode/nozzle bars are cut radially, and the cut edges folded in and kept in position between the sides of the bars and the sides of the slots on the finishing wheels. With fixed-abrasive finishing, the electrolyte need not contain suspended abrasive. In all cases, the direction of the current flow through the side of the workpiece is being controlled by a switch, which switches the current from side to

side of the workpiece periodically to ensure uniform finishing on both sides of the workpiece.

In another embodiment, the abrasive bars are mounted on a honing head, with some cathode bars mounted adjacent to the abrasive bars such that the cathode bars inscribe a smaller cylinder than that by the abrasive bars so that the cathode bars maintain small consistent cathode gaps with the bore surface when the honing head is journaled in a cylindrical bore; the electrolytic solution is continuously being supplied into the bore and filled the cathode gaps, thereby completing the electric circuit and allowing a current to pass through the bore surface to the cathode bars, thus conducting electrolytic polishing in conjunction with abrasive finishing.

In this combined process of electrolytic polishing and abrasive super-finishing, the surface finish is superior to that produced by mechanical abrasive finishing; the material removal rates are higher and, therefore, improves the efficiency of the conventional processes. The advantages of this invention are smoother surface finish, which may be as low as substantially less than 7 Å, more planar, atomically cleaner and practically devoid of both process debris and process burrs.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings which are incorporated into and constitute a part of the description of the invention, illustrate embodiments of the invention and serve to explain the principles of the invention. It is understood, however, that the drawings are designed for purpose of illustration only, and not as a definition of the limits of the invention for which references should be made to the claims at the end of the description.

FIG 1 shows the plan view of the lower polishing wheel with pad, workpiece, workpiece carriers, cathodes, inner and outer rings of a double-side polishing method;

the upper polishing wheel with its polishing pad and cathodes are not shown for purpose of clarity.

FIG 2 shows an oblique view of a small part of the double-side polishing method and illustrates the principle of the combined electrolytic polishing and abrasive polishing process; the outer ring is not shown for purpose of clarity.

FIG 3 shows the principle of double-side polishing/texturing of a singular workpiece using the combined electrolytic polishing and abrasive method; the clamp and shaft details are not shown for purpose of clarity.

FIG 4 shows a finishing wheel comprising of a metal base and a plurality of abrasive blocks, with the abrasive blocks forming the cathode slots in between the blocks.

FIG 5 shows a honing head with a plurality of abrasive bars and cathode bars.

LIST OF REFERENCE NUMERALS

1	upper polishing wheel	2	lower polishing wheel
3	upper polishing pad	4	lower polishing pad
5	outer carrier drive ring	6	inner carrier drive ring
7,7a,7b	workpiece	8	insulated metal carrier
9,9a	electrolytic solution	10,10a,10c	cathode bar
11	switch	12,13	texturing wheel
14,15	texturing pad	16	cathode-shaped nozzle bar
17	rigid abrasive block	18	metal base of bonded wheel
19	abrasive bar of honing head	20	mounting member of honing head

DESCRIPTION OF THE EMBODIMENTS OF THE INVENTION

Referring to the drawings, FIG 1 and 2 show an embodiment of the present invention. The upper polishing wheel (1) and lower polishing wheel (2) have the porous polishing pads (3 and 4) being pasted on by means of pressure-sensitive adhesive; the polishing wheels may have rotation A or B, or A and B. This polishing machine may have a powered outer ring (5) or it may have a fixed outer ring (5), depending on the design of each machine. The inner drive ring (6) is usually powered. The inner and outer rings may generate rotation C at the workpieces (7). The metal carriers (8) have a plurality of hollow sections; the carrier surfaces are being covered with an electrical insulator (such as epoxy or fibre-glass composite by coating, laminating or bonding), which is both compatible with the electrolytic polishing solution (9) and is durable enough to withstand the abrasive effect of the polishing solution. Needless to say, the carriers (8) are slightly thinner than the planar workpieces (7).

The outer (drive) ring (5) and inner drive ring (6) are electrically isolated from the body of the machine but either is, or both are, connected to the positive terminal of a power supply. During the process, the workpieces are in contact with the carriers, which in turn are in contact with the inner and outer rings. In this way, the workpieces are made anodic and is necessary for electrolytic polishing. The cathodes (10) are prismatic bars located in the radial slots on the upper and lower polishing wheels (1 and 2), with the polishing pad (3,4) at the cathodes being cut and the cut edges carefully folded in and kept in position between the sides of the cathode bar (10) and the sides of the slots on the polishing wheels (1,2). The cathodes (10) are effectively connected to the body of the machine, which in turn is connected to the negative terminal of the power supply, directly or through a switch (11). However, either the upper part of the body of the machine or the upper polishing wheel is preferably electrically isolated from the rest of the machine, the advantage of which will be apparent in the following paragraphs. The cathodes (10) must maintain consistent cathode gap of, substantially 0.4 mm, with the workpiece surfaces when subjected to the operating process parameters of pad compressibility and applied pressure. This

cathode gap of substantially 0.4 mm is preferred because it is big enough to prevent arcing at the workpiece, and yet not too big as to necessitate both a higher flow of the electrolytic solution (9) and higher electrolyte content. In practice, a cathode gap of less than 1 mm can be used.

In this polishing process, the workpieces (7) are located in the hollow portions of the carriers (8); a normal pressure is applied on the workpieces (7) through the polishing wheels (1,2) and the workpieces are being pushed over the polishing pads (3,4) as the polishing wheels and carrier drive rings rotate. The polishing pressure may be 0.03 to 0.5 kgF/cm². The electrolytic polishing solution (9) is supplied through holes in both the upper polishing wheel (1) and upper polishing pad (3), or by other means, such as dispensing nozzle bars in the shape of the cathodes. This solution (9) is ionic and with the DC power supply being switched on, the polishing solution (9) continuously fills the cathode gap between the workpieces (7) and cathodes (10) and completes the electrical circuit and a current flows through the workpiece (7) surfaces, thereby, conducting electrolytic polishing. In the regions between the cathodes, the abrasive particles are caught on the surfaces of the porous polishing pads (3,4) and their cutting edges make fine cuts on the workpiece (7) surfaces. The ridges of such abrasive cuts go over the cathodes (10) and due to the charge concentration at the ridges, they are electrolytically dissolved. With a balance of current level, number of cathodes, abrasive effect controlled by both the abrasive size and pore size of the pad, normal pressure and process time, the final finish of the workpiece surfaces are superior to that produced by only the abrasive effect in conventional polishing. Typical average roughness of less than 7Å is easily achieved and the surface finish is more planar, atomically cleaner and practically devoid of both polishing debris and process burrs.

The electrolytic polishing solution contains a minute amount of abrasive, substantially of 0.02 to 5% by weight, 0.1 to 25% of phosphoric acid, 0.1 to 5% of sequestering agent (such as sodium salt of EDTA), 2 to 25% of cutting coolant and the rest is made up of water. For example, when polishing nickel-phosphorus plated disks, the

electrolytic solution may contain substantially of 0.03% of diamond or alumina abrasive, whose mean particle size is 0.3 μm , 1% of phosphoric acid, 0.5% of tetra-sodium EDTA, 5% of coolant and the balance water. The coolant is a proprietary mixture of coolant and dispersant, and can be obtained from Nihon Micro Coating Limited in Japan. This combination of electrolyte is preferred from the economic point of consideration. However, with lower cost abrasive, such as alumina, the percentage used may be increased without affecting the process of this invention. Similarly, the coolant may be increased to provide better abrasive finish, especially at the beginning of the process when the electrolytic polishing effect is building up. When polishing the unplated aluminium substrate, the phosphoric acid concentration may be increased to 10% or more to increase the conductivity of the electrolyte and to afford a faster material removal rate. The process of this invention is particularly advantageous in polishing metallurgically soft and tough material surfaces, such as aluminium. Sequestering agents may not be necessary for the process but it is useful to reduce deposits on the cathodes; other di- or tri-valent ionic salts, such as sulphates and phosphates may be added and the phosphoric acid concentration may then be reduced, so as to increase the solution's pH when necessary; for example, tri-sodium phosphates was used during experimentation.

The power supply output is normally direct-current. For ease of control of both the equipment and the amount of material removal, the output is simply set to give constant current, in which case, the voltage is determined by the size of the power supply and the current limit, cathode gap and electrolyte compositions. Constant voltage mode is equally suitable, and the choice depends on the end-user. The voltage used should be in the safety range, of say below 50V, but preferably at or below 24V. For example, during experimentation, using the above electrolytic polishing solution and a current of 3A, the voltage was approximately 6 to 10 V and the power supply could deliver 10 A at or below 15 V; the power supply in use was obtained from Sansha Electric Manufacturing of Japan. The material removal rate is directly proportional to the current and process time; to control the amount of abrasive

polishing in combination with electrolytic polishing, the current or voltage may be varied periodically throughout the process cycle or for the later part of the process cycle, as and when necessary.

To ensure uniform polishing on both sides of the workpieces, the direction of the current flow through the workpiece surfaces is controlled by a switch (11), which periodically alternates the current from side to side of the workpieces. For example, during experimentation, the polishing wheel speed was 50 RPM and the switch alternated once every two seconds.

FIG 3 shows another embodiment of the present invention. The texturing wheels (12, 13) are similar in function to the polishing wheels (1,2). The texturing pads (14, 15) may essentially be the same as the porous polishing pad (3,4) or may be a flocked material, which may be pasted on the texturing wheels by means of pressure-sensitive adhesive. The workpiece (7a) may be held by a clamp on either its inner or the outer circumference, with the clamp centre-line coinciding with that of the workpiece and texturing wheels. The clamp is connected to the positive terminal of a power supply, so is the workpiece. The clamp details are not shown for purpose of clarity. Either the workpiece or the texturing wheels are relatively powered, or both can be separately powered but in opposite directions, or some combinations of rotation. A simple method is to rotate the workpiece (7a) while keeping the texturing wheels (12, 13) non-rotatory. Each wheel has a plurality of cathode bars (10a) located in radial slots and the cathode bars maintain consistent cathode gap of substantially 0.4 mm with the workpiece surfaces. The electrolytic solution (9a) can be dispensed through a plurality of cathode-like nozzle bar (16). The nozzle bar (16) may be made of an electrical insulator, such as plastic or ceramic and which is compatible with the electrolytic solution. It is possible to machine internal cavity in the cathodes and modify the cathode bars (10a) as solution dispensing nozzle bars, but the outlets of the nozzle must be chamfered to ensure that there are no charge concentrations; charge concentration may cause non-uniform electrolytic polishing on the workpiece

surfaces. The texturing pad at the cathode/nozzle bars are cut radially; the cut edges are folded in and kept in position between the sides of the slot and the sides of the cathode/nozzle bar.

After a workpiece (7a) is clamped, the texturing wheels (12, 13) are moved inward and sandwiched the workpiece; the normal pressure on the workpiece can be set and the positions of the wheels being located by the larger force, F1 or F2. The final workpiece position must have a small axial float to ensure that the pressure on both sides of the workpiece is uniform. Similar to the previous embodiment, the texturing wheels (12, 13) are electrically isolated from each other. Also to ensure uniform combined electrolytic polishing and abrasive polishing/texturing, the texturing wheels are connected to a switch (11), which periodically alternates the current from side to side of the workpiece (7a).

The electrolytic solution for texturing is essentially the same as that for polishing, but the abrasive may be more coarse, for example, the mean abrasive size may be $0.5\ \mu\text{m}$ and the pressure from the pad may be 0.2 to $1\ \text{kgF/cm}^2$. By using a finer abrasive in the electrolytic solution, polishing instead of texturing, can be performed without any other changes in process parameters.

Referring to FIG 3, the axis of the texturing wheels, workpiece and clamp may be horizontal or vertical without affecting the principle of the process of this invention. The advantage of this embodiment is that the flatness of the texturing wheels is easily controlled and, thus, results in more planar textured/polished workpiece surfaces. Typical roughness of less than $7\ \text{\AA}$ is easily achieved and the surface finish is atomically clean and practically devoid of both texturing debris and process burrs.

For both the above embodiments, instead of porous polishing pads or flocked material, abrasive pads may be used and are similarly disposed on the polishing/texturing wheel by means of pressure-sensitive adhesive. However, the

electrolytic solution need not contain suspended abrasive, since the abrasive is already compounded into the pad material.

In another variation, see Fig 4, instead of applying polishing/abrasive pad onto the polishing/texturing wheel, rigid blocks of abrasive (17) may be bonded onto a metallic base (18), such that adjacent blocks are not in contact but form radial slots, which are similar in dimensions and function as the slots described for the polishing/texturing wheels in the previous embodiments; this surfacing wheel may be used instead of the above polishing/texturing wheels. The cathode bars (10, 10a) should be mounted in the slots on means to enable adjustment of the cathode gap when the finishing surface of the abrasive block is worn out or dressed; cathode gap of substantially 0.4 mm is usually preferred. As usual, the cathode and the metal base are connected to the negative terminal of the power supply. As fixed-abrasive is used, the electrolytic solution need not contain suspended abrasive.

Fig 5 shows yet another embodiment. The abrasive bars (19) are mounted on some support members (20) of a honing head which have means to be displaced radially but maintaining cylindricity of the abrasive bars. On similar mounting members are mounted the cathode bars (10c), which have means to enable adjustment of the cathode bars height so that they inscribe a smaller concentric cylinder with that by the abrasive bars; in this way, the cathode bars maintain small consistent cathode gaps with the cylindrical bore surface when the honing head is journaled in the bore; cathode gap of substantially 0.4 mm is preferred. It is also possible to simply locate the cathode bars (10c) onto one side of some of the mounting members (20) of the abrasive bar such that the cathode bars are adjacent to the abrasive bars but maintain small cathode gaps with the bore surface; means must be provided to adjust the cathode gap when the abrasive bars are worn out.

As in the other embodiments, the cylindrical bore (workpiece) (7b) surface is connected to the positive terminal of a power supply, while the cathode to the

negative terminal. The electrolytic solution need not contain suspended abrasive; when the electrolytic solution is continuously supplied into the bore and the honing head is both expanded against the bore surface and journaled in it, the cathode gap is filled with the electrolytic solution and a current flowed through the bore surface to the cathodes, thus conducting electrolytic polishing in conjunction with abrasive finishing. To ensure uniform surface finish, the honing head is reciprocated repeated in the bore by means of an actuator, for example.

In the above embodiments, the cathode bars (10,10a,10c) are made from stainless steel; however, steel that is plated with metal like nickel, chrome or platinum, for example, can be used instead. The main consideration is to provide a clean cathode surface, and the plated metal should not rust and not generate particles.

In all the embodiments of this invention, the material removal rate of this combined electrolytic polishing and abrasive super-finishing process is significantly higher than the conventional process, thus reducing the process time and, therefore, increasing both the process efficiency and productivity. Also to ensure uniform surface finishing, the amount of abrasive super-finishing in combination with electrolytic polishing can easily be controlled by periodically varying the current throughout the process cycle or for the later part of the process cycle, as and when necessary.

The above description contains many specific examples. However, other variations are also possible for those skilled in the art of polishing. For example, by having a surface finishing plate (with cathodes located in slots and the polishing/abrasive material cut and folded in and maintaining small cathode gaps) being reciprocated in a plane relative to the workpiece, polishing of a large planar surface is easily carried out, such as in the super-finishing of stainless steel sheets; finishing of a spherical surface, or any surface of revolution, using the process of this invention can easily be implemented.

What is claimed is:

CLAIM 1

A combined electrolytic polishing and abrasive super-finishing process comprising of:

- (a) the metallic surfaces of a plurality of planar workpieces being sandwiched between two finishing wheels,
- (b) a plurality of metal carriers, each with a plurality of hollow sections where the workpieces are located and said carrier surfaces are covered with an electrical insulator, and both said carriers and said workpieces are connected to the anode through the carrier drive ring,
- (c) a plurality of cathode bars are located in radial slots on the said finishing wheels but maintaining small cathode gaps with the said metallic surfaces,
- (d) an electrolytic solution, and
- (e) a power supply delivering a current to the said metallic surface and said cathode bars via the said electrolytic solution, which is continuously being supplied and filled the said cathode gaps, thus conducting electrolytic polishing in conjunction with abrasive finishing.

CLAIM 2

A combined electrolytic polishing and abrasive super-finishing process in Claim 1, in which the said metal carrier surfaces are covered with an electrical insulator by coating, laminating, bonding and by other methods so that said carrier surfaces are not electrolytically polished during the process and afford a durable surface to the said carriers.

CLAIM 3

A combined electrolytic polishing and abrasive super-finishing process comprising of:

- (a) the metallic surfaces of a singular planar workpiece being sandwiched between two finishing wheels,
- (b) workpiece clamp being concentric with the said finishing wheels and connected to the anode,

- (c) a plurality of cathode bars located in the radial slots on the said finishing wheels and maintaining small cathode gaps with the said metallic surface,
- (d) an electrolytic solution, and
- (e) a power supply delivering a current to the said metallic surface and said cathode bars via the said electrolytic solution, which is continuously being supplied and filled the said cathode gaps, thus conducting electrolytic polishing in conjunction with abrasive finishing.

CLAIM 4

A combined electrolytic polishing and abrasive super-finishing process in Claims 1 and 3, further includes said cathode bars having internal cavity and thus having additional function as electrolytic solution dispensing nozzle bars, or further includes cathode-like nozzle bars being made of an insulator.

CLAIM 5

A combined electrolytic polishing and abrasive super-finishing process in Claims 1 and 3, in which the said finishing wheel has a metallic base and on the working side is disposed either a porous polishing pad, flocked material pad or an abrasive pad, or is bonded a plurality of abrasive block.

CLAIM 6

A combined electrolytic polishing and abrasive super-finishing process in Claims 1 and 3, further includes a switch to control the current flow through the side of the said workpiece and switches it from side to side of the workpiece periodically to ensure uniform finishing on both sides of the workpiece.

CLAIM 7

A combined electrolytic polishing and abrasive super-finishing process in Claims 1, 3 and 5, in which the finishing wheel is disposed a porous polishing pad or a flocked material pad and the said electrolytic solution further includes suspended abrasive particles.

CLAIM 8

A combined electrolytic polishing and abrasive super-finishing process in Claims 1, 3, 4, 5 and 7, in which the said polishing pad/flocked material pad/abrasive pad at the said cathode bars/nozzle bars is cut radially, the said cut edges folded in and kept in position between the sides of the said bar and the sides of the slots on the said finishing wheels.

CLAIM 9

A combined electrolytic polishing and abrasive super-finishing process in Claims 1, 3, 4, 5 and 7, in which porous polishing pad and electrolytic solution with suspended abrasive are used and the resulting surface finish is uniform and smoother, average roughness as low as substantially less than 7 Å, more planar, atomically cleaner and practically devoid of both process debris and process burrs.

CLAIM 10

A combined electrolytic polishing and abrasive super-finishing process comprising of:

- (a) the metallic surface of a cylindrical bore, which is connected to the anode,
- (b) a honing head with a plurality of abrasive bars, which are located on some mounting members that have means to be displaced radially and maintaining cylindricity of the abrasive bars,
- (c) a plurality of cathode bars on some said mounting members of the said honing head that have means to adjust and maintain small cathode gaps with the said bore surface when the said honing head is journaled in said cylindrical bore,

- (d) an electrolytic solution, and
- (e) a power supply delivering a current to the said bore surface and said cathode bars via the said electrolytic solution, which is continuously being supplied into the said bore and filled the said cathode gaps, thus conducting electrolytic polishing in conjunction with abrasive finishing.

CLAIM 11

A combined electrolytic polishing and abrasive super-finishing process in Claims 1, 3 and 10, further includes the cathode bar material as stainless steel or the said cathode is plated to keep the surface clean of rust and said plated metal does not generate particles.

CLAIM 12

A combined electrolytic polishing and abrasive super-finishing process in Claims 1, 3 and 10, in which the surface finish is more uniform and of a smoother profile, atomically cleaner and practically devoid of both process debris and process burrs.

CLAIM 13

A combined electrolytic polishing and abrasive super-finishing process in Claims 1, 3 and 10, in which the process time is shorter than the conventional process, thus improving both the process efficiency and process productivity.

Title: Combined Electrolytic Polishing and Abrasive Super-finishing Process

ABSTRACT:

A combined process of electrolytic polishing and abrasive super-finishing of metal surface, provides a method of super-finishing that yield a uniform and smoother finish of as low as less than 7Å, more planar and atomically cleaner finish and at a higher process efficiency. The workpiece (7,7a) is sandwiched between two polishing pads (3,4) or texturing pads (14, 15); the workpiece (7,7a) is connected to the anode; the cathodes (10,10a) are located in the radial slots in the finishing wheels (1, 2, 12, 13); the electrolytic solution (9,9a) is continuously supplied to the finishing wheel surface and filled the cathode gaps between the cathode and workpiece surface, thus allowing a current to flow through the metallic surface of the workpiece to the cathode and, thereby, conducts electrolytic polishing in conjunction with abrasive super-finishing. A switch (11), at the cathode side, controls the current flow from side to side of the workpiece periodically to ensure uniform processing on both sides of the workpiece.

Instead of using suspended abrasive, each finishing wheels (1,2,12,13) may be disposed an abrasive pad but the electrolytic solution need not contain suspended abrasive. In a similar manner, rigid abrasive blocks (17) may be bonded onto a metallic base (18) to replace the polishing/texturing wheels but with provision of radial cathode slots as usual and means to adjust the cathode gap when the abrasive surface is worn out or dressed.

In like manner, abrasive (19) and cathode (10c) bars are mounted on a honing head, with the cathode bars having means to adjust the cathode gap with the cylindrical bore (7b) surface, enables combined electrolytic polishing and abrasive finishing of cylindrical bore surface. Finishing of planar and other surface of revolution can easily be implemented.

Selection Diagram: FIG 2

1/4

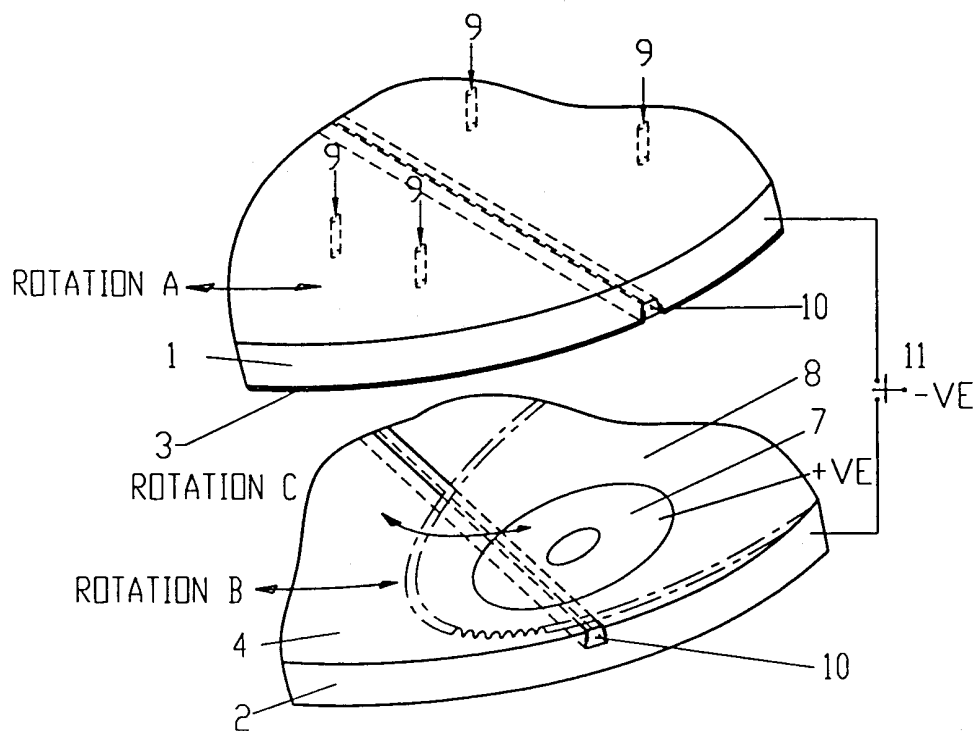
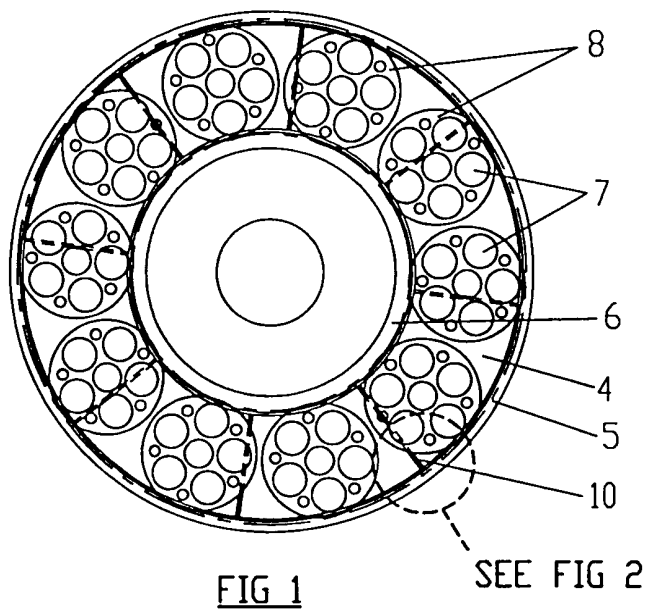


FIG 2

2/4

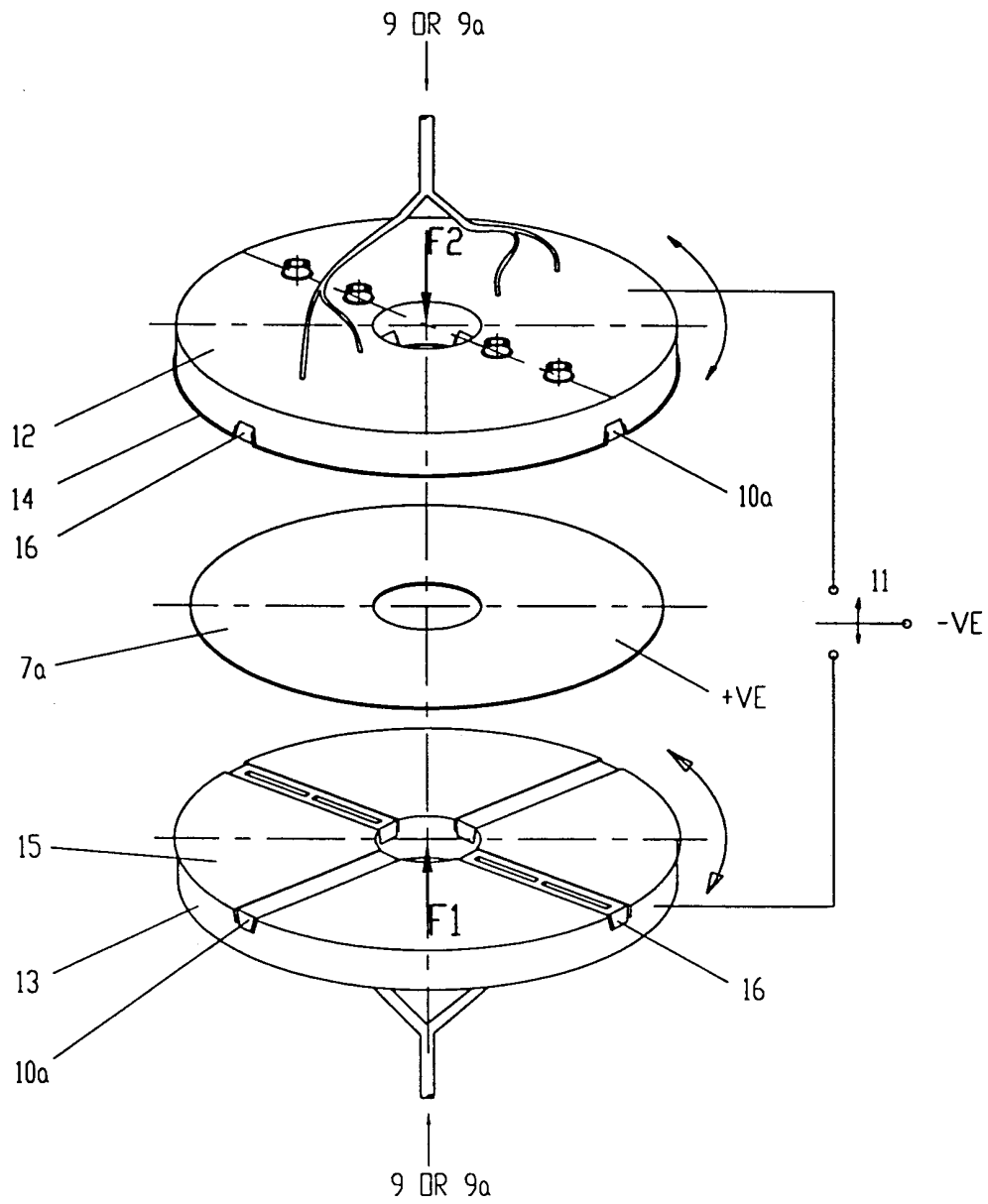


FIG 3

3/4

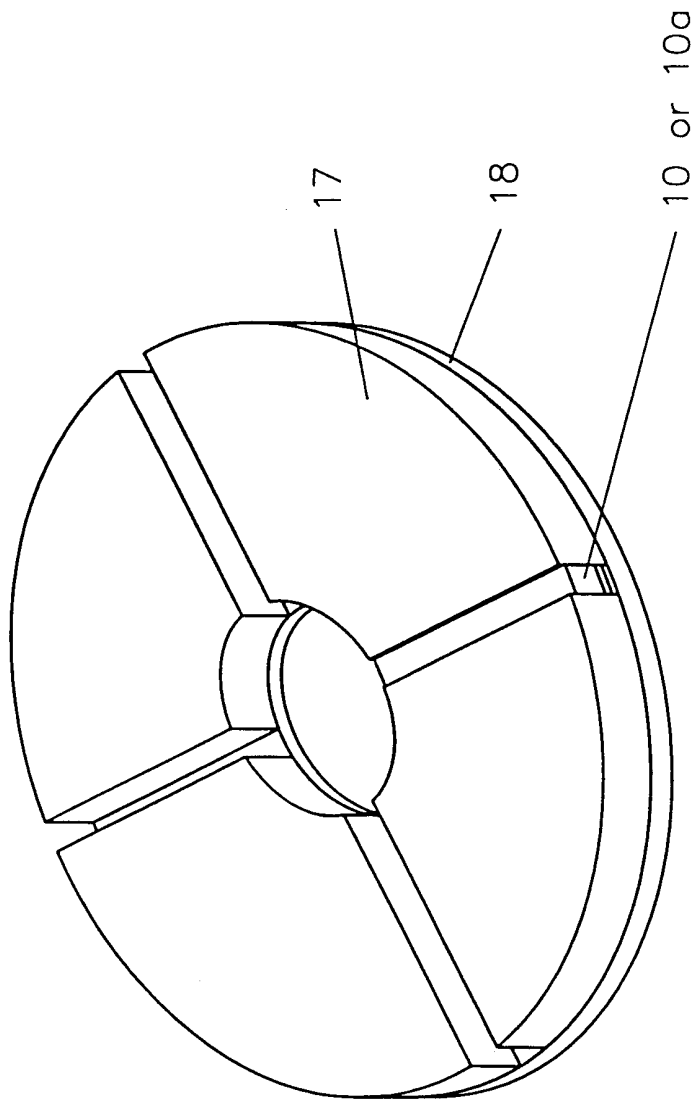


Fig 4

4/4

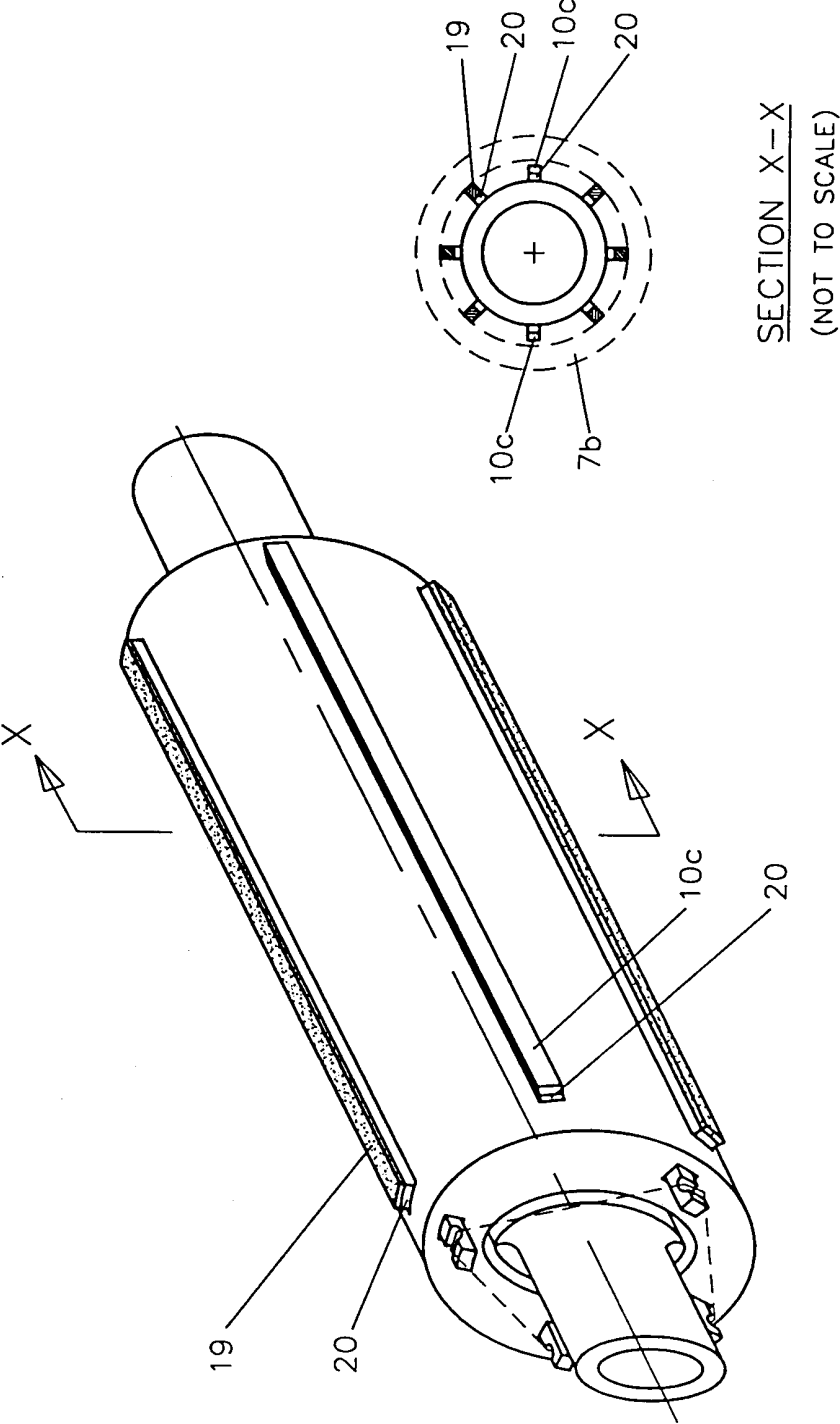


Fig 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SG99/00127

A. CLASSIFICATION OF SUBJECT MATTER		
Int Cl ⁶ : B23H 3/00, 5/06, 5/08 B24D 17/00 C25F 3/16		
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) IPC B23H 3/00, 5/06, 5/08 B24D 17/00 C25F 3/16		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched AU: IPC as above		
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.
A	WO 98/28101 A (UNIQUE TECHNOLOGY INTERNATIONAL PRIVATE LIMITED) 2 July 1998 Whole document	1-13
A	WO 99/10569 A (UNIQUE TECHNOLOGY INTERNATIONAL PRIVATE LIMITED) 4 March 1999 Whole document	1-13
A	EP 0576937 A (RIKAGAKU KENKYUSHO) 5 January 1994 Whole document	1-13
☒ 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 27 January 2000		Date of mailing of the international search report 11 FEB 2000
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SG99/00127

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4140598 A (KIMOTO et al). 20 February 1979 Whole document	1-13

Information on patent family members

PCT/SG99/00127

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

END OF ANNEX