



Description

The present invention concerns an electrode for electrochemical machining comprised of a conductive body having an interior portion shaped for conveying electrolyte to the tip of the electrode and a conductive closure covering the tip of the electrode, the closure allowing electrolyte to flow from the interior portion to the exterior portion of the electrode, the closure having a plurality of through holes of less than 400 micrometer exit diameter and the cross-sectional flow area of the hole exits at the exterior surface of the closure being less than 50 percent of the cross-sectional area of the closure.

The invention also concerns a process of electrochemically machining a workpiece to remove material uniformly therefrom, in utilizing an electrode comprised of a conductive body having an interior portion shaped for conveying electrolyte to the tip of the electrode and a conductive closure covering the tip of the electrode, the closure allowing electrolyte to flow from the interior portion to the exterior portion of the electrode, the closure having a plurality of through holes of less than 400 micrometer exit diameter and the cross-sectional flow area of the hole exits at the exterior surface of the closure being less than 50 percent of the cross-sectional area of the closure, wherein said electrode has a working face spaced apart by a gap G from the workpiece surface, electrolyte is flowed under pressure through the electrode working face and then through the gap G flowing the electrolyte through a plurality of small passages distributed over said working face.

Electrochemical machining (ECM) has been widely used in the gas turbine industry to machine tough alloys. Over the past two decades, there has been considerable progress with respect to machinery and specialized techniques for particular material. Still, new demands arise from time to time, and the present invention arose from the search for a solution to a particular problem.

The DE-A-1 933 455 discloses an electrode for electrochemical machining comprised of a conductive body having an interior portion shaped for conveying electrolyte to the tip of the electrode and a porous conductive closure covering the tip of the electrode, the closure allowing electrolyte to flow from the interior portion to the exterior portion of the electrode, the porous closure having a plurality of through holes of less than 400 μ m exit diameter and the cross-sectional flow area of the holes exits at the exterior surface of the closure being less than 50 percent of the cross-sectional area of the closure.

The DE-A-2 313 167 discloses a process of electrochemically machining a workpiece in utilizing an electrode made of a porous powder metal working surface through which the flow of electrolyte is made.

The tips of superalloy turbine blades in gas turbine engines occasionally come in contact with the circumscribing air seal. When this occurs, the mode of interaction and wear between the components must be controlled. As a result, specialized materials, have been applied to the tip of the blade, to act as an abrasive when in contact with the air seal. Owing to the high temperatures and severe environment, most conventional abrasives are not suitable. An abrasive material which has been found to be useful is comprised of a metal matrix containing a multiplicity of ceramic particulates; specifically, a nickel or cobalt alloy matrix containing particulates of silicon carbide. US-A-4,249,913 to Johnson et al, commonly owned by the present assignee, describes such a material, and the disclosure thereof is incorporated by reference. See also US-A-4,227,703 to Stalker et al.

It is now appreciated that to enhance the performance of these specialized abrasive materials, the ceramic grains on the tips of the turbine blades should be exposed, or relieved of their surrounding matrix material, so that they project slightly above the surface of the matrix. Inasmuch as the abrasive is a composite of ceramic and metal and since the metal is a relatively complex superalloy, it is not a simple matter to uniformly remove the matrix. About 0.15 mm of matrix material has to be removed, but the removal must be uniform in depth across the surface and from one blade to the next, and the removal technique must not substantially undercut the silicon carbide grains. Areas of the superalloy blade adjacent the abrasive should not be attacked.

Simple chemical milling works but is not optimal owing to the complexity of the alloy and the selective attack of different phases. Furthermore, chemical milling is slow. ECM is preferred because it is a high rate production process.

In conventional ECM, an electrode is placed in proximity to the workpiece and an electric potential is placed across the electrode and the workpiece. Electrolyte is forced into the gap between the electrode and the workpiece, and as material is removed, the electrode is advanced toward the workpiece. Typically, the electrode is hollow and the electrolyte flows internally along the electrode, issuing through a hole, slot, or some other like aperture at the working face of the electrode. However, in such an instance there will tend to be left on the surface of the workpiece a small protuberance at the vicinity of the orifice through which the electrolyte issues. See Figures 1 and 3 of US-A-3,723,268 to Johns et al. In most instances, these protuberances are not a problem. But in certain situations where blind holes are drilled, supplemental machining operations must be used to remove the protuberance and achieve a flat bottomed hole. In the removal of matrix from the silicon carbide and metal composite material, an electrode which leaves protuberances or substantial local high spots is not acceptable. Of course, the electrolyte need not be introduced through the internal passages of the ECM electrode but instead can be cross flowed through the gap. However, such procedures require often times complex apparatus to channel the flow across the end of the electrode.

In both the conventional procedures there is a further tendency for uneven matrix removal since the

insoluble ceramic grains create stagnant electrolyte flow areas. It has been found that temperature rise and other adverse effects in stagnation areas will tend to produce undercut or uneven removal of matrix. The dissimilar electrical properties of the ceramic and metal further complicate analysis of what occurs during ECM.

5 It is an object of the invention to provide an improved method of electrochemical machining where very uniform surfaces must be produced in metals and where small amounts of material must be removed from metal-ceramic composites.

The electrode of the present invention is characterized in that said closure is made of a porous powder material and that said closure has a flow rate in the range of 3—8 ml/sec/cm² when the pressure drop
10 across the closure is in the range of 2.5—7.5 kPa.

The method of the present invention is characterized in that said flowing of the electrolyte is made through the working surface of said closure made of a porous powder material, said closure having a flow rate in the range of 3—8 ml/sec/cm² when the pressure drop across said closure is in the range of 2.5—7.5 kPa, the pressure drop of the electrolyte through the portion of the electrode which comprises the working
15 face being greater than the pressure drop of the electrolyte within the gap G, the workpiece surface being made of a composite material comprised of a ceramic particulate in a metal matrix.

The invention involves the use an electrode with a plurality of small passages on its working face. Preferably, the end of a hollow electrode is closed by a porous powder metal sheet. In use, electrolyte flows through a relatively large interior passage and then through the porous working face of the electrode. It
20 then exits from the gap between the electrode face and the workpiece surface being machined. Because of the relation between the electrode working face and the sizes of the interior electrode passages and the gap, the principal pressure drop in the electrolyte flow path is across the working face of the electrode. This means that flow rate is relatively insensitive to the gap. Thus, when the electrode is used to remove matrix material from a surface comprised of insoluble ceramic particulate and metal, the electrolyte and current
25 are both evenly distributed over the surface of the workpiece. Similarly, use of the electrode converts uneven surfaces, such as those made by a conventional ECM electrode with a large central passage to an even surface.

In the preferred practice of the invention the electrode working face is made of sintered powder metal sheet of the type commonly used for filtering. Such sheets have nominal particle size capture ratings of
30 20—100 micrometers, but the individual fluid discharge ports on the working face will range up to four times the nominal rating. The hollow electrode of the invention is configured so that the closure which comprises the working face has an apparent flow path area of less than 50% of the interior channel of the electrode body which is immediately upstream of the closure.

When machining composite ceramic particulate and metal abrasive materials, the size of the fluid
35 discharge ports on the working face will be equal or less than the nominal size of the particulate, to obtain uniform matrix removal. Generally, the gap between the electrode and the workpiece will range from 0.05—0.5 mm, most preferably at about 0.38 mm. In this range, with the preferred 100 micrometer powder metal electrode, and a constant flow rate in the range of about 6 ml/sec/cm² the pressure drop across the electrode will be always two times or greater than the pressure drop in the gap, which of course is greatest
40 for the minimum gap dimension.

Because of the even distribution of electrolyte which is obtained at relatively low electrolyte pressures, of the order of 2.5—7.5 kPa (~25—75 cm of water column) are usable. Thus, instead of jetting from the electrode face, the electrolyte tends to seep. When machining the tip of a turbine blade or other article, unwanted attack away from the working face is prevented by disposing upwardly the electrode working
45 face. Electrolyte discharged from the gap flows downward and away from the workpiece. In the preferred practice of this aspect of the invention the electrolyte pressure is in the range of 2.5—7.5 kPa and the flow rate is in the range 3—8 ml/sec/cm².

Compared to conventional ECM techniques the invention produces uniform finish surfaces and minimizes extraneous workpiece attack. The foregoing and other objects, features and advantages of the
50 present invention will become more apparent from the following description of preferred embodiments and accompanying drawings.

Figure 1 shows how the tip of a turbine blade is electrochemically milled using a porous metal tipped electrode facing vertically up.

Figure 2 shows a composite material of ceramic particulates and metal matrix composite material prior
55 to machining.

Figure 3 shows the material of Figure 2 after electrochemical machining to remove some of the matrix and uniformly expose the grains.

Figure 4 shows in more detail a structure like that of Figure 3 but instead illustrates the types of defects which occur when electrochemical machining is not done correctly.

60 Figure 5 is a partial cross section through the parts shown in Figure 1.

Figure 6 is a photograph of silicon carbide particulate in a nickel alloy matrix after 0.15 mm of matrix has been removed from a flat ground surface.

The present invention is described in terms of the removal of a portion of the matrix metal from a composite material comprised of silicon carbide particulates dispersed in a high temperature alloy of nickel
65 or cobalt, such as are described in the Johnson Patent No. 4,249,913.

Because of its function on a gas turbine blade, this material is referred to herein as an abrasive; but the appellation will be understood to refer to any composite of ceramic particulate and metal.

It will be apparent that the invention is relevant to other materials and other configurations of articles.

The essential processes of electrochemical machining (ECM) are described in the aforementioned Patent No. 3,723,268 and in the book by J. F. Wilson, "Practice and Theory of Electrochemical Machining", Wiley-Interscience, New York (1971). A blade 10 comprised of a hollow body 12 and an abrasive closure 14 at its tip is shown in Figure 1, as it is positioned for electrochemical machining. Figure 2 shows in simplified fashion how the blade tip appears prior to ECM. The surface 16 of the abrasive has been ground to a precise dimension which may be curvilinear or planar. Figures 3 and 6 show how the same structure appears after processing according to the method of the invention. The ceramic particulates 18 project above the matrix metal 20 by an amount A, owing to removal of some of the matrix metal from the surface.

Figure 4 illustrates in detail what happens when ECM is not properly carried out in accord with the invention. All the defects in the Figure may not occur on the same workpiece, but they are shown here in one illustration for convenience. In one deviation, the particulates 18 are surrounded by moats; i.e., they are undercut by selective localized attack of the matrix metal. In a second type of defect, the surface 16 of the matrix metal is uneven across the surface of the workpiece, meaning that the degree of exposure of the various particulates is uneven. In the third type of defect, the side 13 of the abrasive has been electrochemically attacked. All such defects can be deleterious to the performance of the component. When the particulates are undercut, they tend to easily pull out. When the matrix is uneven, the abrasive does not function uniformly across its surface; i.e., the desired effects of controlled removal of the matrix are not obtained. When the workpiece is selectively attacked at regions away from the surface, such as the side, it is potentially weakened.

Figures 1 and 5 illustrate how the invention is practiced. An electrode 26 is configured with a working face 28, shaped according to the area which it is desired to electrochemically machine. The electrode 26 has a hollow body 30 to which is attached a closure 32 made of a porous sintered metal, such as an AISI 316 stainless steel 100 micron metal filter element. The electrode 26 has body parts 30, 34 with interior portions or passages 36 adapted to convey electrolyte through the interior of the electrode to the porous closure, as indicated by the arrows 38. The electrolyte passes through the closure 32 and is discharged towards the workpiece face 16. The workpiece face 16 is spaced apart from the face 28 of the electrode by a gap G. During ECM of the surface 16, current is applied between the electrode and the workpiece. When a small amount of surface material is to be removed, such as 0.02—0.15 mm, the electrode and workpiece are fixed with respect to one another. When more material is desired to be removed from the workpiece, in instances other than those described for the abrasive herein, then the electrode would advance toward the workpiece as removal of a material from the workpiece tended to increase the gap G.

The cross-sectional area of the passage 36 which feeds electrolyte to the closure is greater than the summation of cross-sectional areas of the porous metal closure passages. Therefore, the porous metal closure acts as a metering device. The primary pressure drop along the electrolyte flow path, from inside the electrode body, through the closure, and out the gap is caused to occur at the closure. The flow area of the closure is related to the gap G so that there is relatively little pressure drop in the electrolyte in the gap. As an example, a total pressure of 2.5—7.5 kPa (about 0.3—1 m water column) is supplied when the electrode is a 100 μ m filter element (described in more detail below). With this pressure, the electrolyte gently oozes from the surface of an upward facing electrode working face, forming a meniscus layer of about 1 mm thick. Since the principal pressure drop is across the electrode closure, the flow at different locations across the working face 28 is relatively uniform regardless of whether a workpiece is present or not. This is in contrast to the situation with a conventional electrode having very few large electrode face passages, where the change in the distance G, either by movement or variation in electrode position, or by erosion of the workpiece, will affect the electrolyte flow. And flow at one location on the electrode face will, by its increase or decrease, affect conversely the flow at another location in the workpiece surface.

In the invention, since the porous metal closure causes a relatively high pressure drop of a rather low absolute value, and since the flow is relatively constant, when the workpiece is mounted vertically above the electrode, the electrolyte will fall vertically downward upon issuing from the gap. This prevents unwanted attack of the portions of the workpiece away from the working surface, such as the part 13 without requiring the necessity of masking. It is also found, probably due to the same effects, that there is comparatively little erosion at the edge 40 of the workpiece, compared to that which is found in conventional ECM, whether electrolyte is flowing through the electrode or across the gap from an external supply. Notwithstanding the foregoing, in the best practice of the invention lacquer or other impermeable membrane is applied to the surface 13 as a matter of prudence.

The following more particular descriptions exemplify the practice of the invention when machining an abrasive. The abrasive is comprised of about 30—45 volume percent alumina coated silicon carbide particulate sized between 0.2—0.6 mm, preferably between 35—45 U.S. sieve series size (0.495—0.351 mm opening) in a matrix of nickel or cobalt superalloy, preferably an alloy of US—A—4,152,488 to Shilke et al (which is hereby incorporated by reference). The abrasive is made by hot pressing or plasma spraying processes. The particulate is coated with a nonconductive oxide such as alumina and therefore the ceramic is not conductive of electricity at the voltages used in ECM. From 0.05—0.20 mm of matrix ordinarily must be removed to expose the particulate and enhance the abrasive properties.

The electrode is comprised of 20–100 μm AISI 316 steel filter element material, such as may be obtained from Mott Metallurgical Corp., Farmington, Connecticut, USA. The micrometer designation is a measure of the permeability and refers to the minimum particle which is captured from a fluid stream by the material. A sheet of the sintered stainless steel powder material is welded to an electrode body made of compatible material. The thickness of the powder metal closure is chosen according to structural needs and preferably is relatively thin; a 2.3 mm thick piece has been found satisfactory. The working face of the electrode is shaped according to the contour of the workpiece (or that which is desired if the contour is to be changed).

The electrode circumferential dimensions preferably fit the workpiece as shown in Figure 5, but may be larger or smaller. The electrode is fixedly positioned with respect to the workpiece so the gap G is 0.05–0.5 mm, preferably 0.25–0.38 mm. The electrolyte may be selected from those known in the art. Preferably it is comprised of 0.4 kg/l sodium nitrate in water with caustic soda or nitric acid added as needed to obtain a pH of 7–9. A specific gravity of 1.23–1.25 at 38°C is maintained during operation by adding water or sodium nitrate. The electrolyte is pressurized to at least 2.5 kPa, as needed to obtain a flow rate of at least 3 ml/sec/cm² through the electrode working face. Higher pressures are needed with finer pores size electrodes. For a 100 μm electrode material the preferred flow rate of 6.5 ml/sec/cm² is obtained with an upstream pressure of about 5 kPa. The electrolyte is filtered, preferably with a 0.45 μm absolute membrane final filter (such as a Type 12571 Filter, from Gelman Sciences Company, Ann Arbor, Michigan) to avoid particulates which may cumulatively plug the electrode during use.

A constant voltage power supply is connected across the gap. For the above-mentioned preferred material and parameters, a voltage of 10.5V will be applied, producing an initial current of about 11 A/cm², decreasing to about 9 A/cm² as matrix is removed and the effective gap widens from the starting point of 0.38 mm to the final 0.51 mm. Different voltages and current densities may be used to vary the rate of removal. However, the current density is desirably maintained in the generally low range indicated, so that the exiting electrolyte temperature does not heat to greater than about 50–60°C.

With respect to the foregoing ranges, limited experiments have been run. As electrodes, filter element materials having nominal ratings of 0.5, 2, 10, 20, 40 and 100 μm were tested and found usable. However, those less than 20 μm are more prone to eventual plugging and are to be avoided. About 35–50% of the working face area of an electrode made of the preferred 20–100 μm material is the electrolyte passage exit area, based on the typical porosity of the powder metal material. The passages tend to be larger in nominal diameter than the nominal micron rating. Thus a 100 μm material may have passage exits of varying dimension, from very small to up to 400 μm . However, as indicated in connection with the Table below, the tortuous flow path through the powder metal closure provides a pressure drop substantially greater than the apparent porosity would suggest. The upper size limit of usable electrode closure was not determined but if the passages become too big then irregular surface finishes will eventually be obtained, as are obtained with electrodes having a single large central port. In the present invention the ceramic particulates are nominally 350–500 μm diameter and thus the preferred electrode nominal passage size is equal or less than the particulate size. This means not only that there will be even discharge of electrolyte, but that there will be no significant areas, on the scale of the particulate, where there will be an absence of conductive electrode material due to the presence of an electrode passage opening on the working face. In summary, the multiplicity of passages smaller than the size of the particulate ensures even distribution of electrolyte and even distribution of electrical current.

While a porous sintered powder metal is easiest to fabricate, the closure in my invention can be made by other means, such as by drilling a multiplicity of very small holes through the surface of a solid piece of metal. In such an instance, the diameter and spacing of the holes would approximate the surface characteristics of the powder metal which we described above. And of course the electrode may be made of other materials, such as copper, brass, and the like, as are known to be useful in ECM electrodes.

Electrolyte flow through the electrode working face can ordinarily be affected by the gap during machining. The gap must be great enough to ensure that the predominate pressure drop is through the electrode and not in the gap. Thus in the exemplary case of the 100 μm electrode, the gap should not be less than 0.05 mm and desirably is 0.38 mm. Table 1 shows data illustrative of standard sodium nitrate electrolyte flow behavior for an electrode which was airfoil shaped the same as the workpiece. The cross-sectional area of the electrode working face was about 4.5 cm² and the peripheral length was about 120 mm, meaning that for a 0.38 mm gap the peripheral discharge area was about 0.45 mm², substantially less than the working face area.

TABLE 1
Electrolyte flow path pressure drop for different gaps at constant flow rate

Gap (m)	Total ΔP (kPa)	Electrode ΔP (kPa)	Gap ΔP (kPa)
∞	5	5	—
0.38	5.5	5	0.5
0.13	6.2	5	0.7
0.05	7.5	5	2.5

The electrolyte flow was constant at 0.65 ml/s/cm^2 and thus the pressure drop (ΔP) across the electrode working face (or closure) was constant at the value measured when no workpiece was present ($\infty=0$ in the Table). It is seen that the electrode pressure drop is always more than two times the gap pressure drop, even for the very small 0.05 mm gap. As a corollary, the data show that if constant pressure were supplied, the system flow will vary conversely to the pressure data. Thus, flow is relatively insensitive to gap within the overall, and especially, the preferred operating range. The preferred starting gap is relatively large at about 0.38 mm when machining the abrasive because with larger gaps there is less sensitivity in current density (and thus material removal) due to planar misalignment of the electrode face with the workpiece face. If the gap becomes too large, substantially greater than 0.5 mm, then the surface velocities of electrolyte characteristic of ECM will not be obtained. Stagnation, heating, and even boiling at the workpiece surface may be encountered. The process will be converted into one characterizable as electropolishing and current densities will necessarily be lowered, beneath those of about 8 A/cm^2 characteristic of ECM. Generally, it has been found that when the gap is smaller than about 0.3—0.4 mm or if there is insufficient flow of electrolyte, there will be a tendency for undercutting of the particulate and uneven removal. That is, there is preferential removal of material proximate the grains. These results are attributed to the peculiar electrical character of the ceramic-metal material. Additionally, while on a macro-scale the particulate is uniformly distributed in the matrix, on a micro-scale there are regions between small agglomerations of particulates where stagnation of electrolyte takes place, as can be seen in Figure 6.

In the invention, the even distribution of electrolyte obtained by the great many closely spaced orifices of the electrode permits the use of unusually low flows. These enable low resultant exit velocities from the gap, which combined with the orientation of electrode and workpiece, prevent the electrolyte from flowing around the workpiece and causing unwanted, extraneous attack.

As described, the inventive electrode is useful for removing material used uniformly from any surface. Thus, if uniform bottomed blind holes are desired, an electrode can be accordingly shaped and plunged into a workpiece. For various reasons, it may be desirable to use the more conventional type of electrode having a large hollow internal passage which discharges fluid at a high velocity and flow rate, compared to that which is possible with the powder metal cap. Using this, a blind hole which has a small raised portion in the center will be created. To eliminate the protuberance and provide a flat bottom hole, the first electrode is removed when the desired depth is virtually achieved. Then, an electrode according to the invention is placed into the hole. This second electrode will have a shape similar to the first electrode, or a shape which is smaller but sufficient to encompass the area where the raised protuberance is. Then, ECM will be conducted to remove the protuberance and smooth the bottom of the hole. Thus, the advantages of high production using conventional electrodes are achieved while obtaining a more uniform shaped cavity than heretofore possible.

Although this invention has been shown and described with respect to a preferred embodiment, it will be understood by those skilled in this art that various changes in form and detail thereof may be made without departing from the scope of the claimed invention.

Claims

1. An electrode (26) for electrochemical machining comprised of a conductive body having an interior portion (34, 36) shaped for conveying electrolyte to the tip of the electrode and a conductive closure (32) covering the tip of the electrode (26), the closure (32) allowing electrolyte to flow from the interior portion (34, 36) to the exterior portion of the electrode (26), the closure (32) having a plurality of through holes of less than 400 micrometer exit diameter and the cross-sectional flow area of the hole exits at the exterior surface of the closure (32) being less than 50 percent of the cross-sectional area of the closure (32), characterized in that said closure (32) is made of a porous powder material and that said closure (32) has a flow rate in the range of $3\text{--}8 \text{ ml/sec/cm}^2$ when the pressure drop across the closure (32) is in the range of $2.5\text{--}7.5 \text{ kPa}$.

2. The electrode according to claim 1 characterized in that the closure (32) is a sintered powder metal closure.
3. The electrode according to claim 1 characterized by a powder metal closure (32) having a filtration rating of 20—100 micrometers.
4. The process of electrochemically machining a workpiece to remove material uniformly therefrom, in utilizing an electrode comprised of a conductive body having an interior portion (34, 36) shaped for conveying electrolyte to the tip of the electrode and a conductive closure (32) covering the tip of the electrode (26), the closure (32) allowing electrolyte to flow from the interior portion (34, 36) to the exterior portion of the electrode (26), the closure (32) having a plurality of through holes of less than 400 micrometer exit diameter and the cross-sectional flow area of the hole exits at the exterior surface of the closure (32) being less than 50 percent of the cross-sectional area of the closure (32), wherein said electrode (26) has a working face (28) spaced apart by a gap G from the workpiece surface (16), electrolyte is flowed under pressure through the electrode working face (26) and then through the gap G flowing the electrolyte through a plurality of small passages distributed over said working face (28), characterized in that said flowing of the electrolyte is made through the working surface of said closure (32) made of a porous powder material, said closure (32) having a flow rate in the range of 3—8 ml/sec/cm² when the pressure drop across said closure (32) is in the range of 2.5—7.5 kPa, the pressure drop of the electrolyte through the portion of the electrode (26) which comprises the working face (28) being greater than the pressure drop of the electrolyte within the gap G, the workpiece surface (16) being made of a composite material comprised of a ceramic particulate in a metal matrix.
5. The method according to claim 4 characterized in that the pressure drop through the working face (28) portion is more than two times the drop within the gap G.
6. The method according to claim 4 characterized by disposing the working face (28) of the electrode (26) vertically upward, and placing the workpiece surface (16) being machined vertically above the working face (28), so that electrolyte issuing from the gap G flows away from the workpiece.
7. The method according to claim 4 characterized in that the porous metal is powder metal filter element material having a filtration rating in the range of 20—100 micrometers.
8. The method of electrochemically machining an uneven surface to produce a more even surface characterized by using the process of claims 4—9.
9. The method of claim 10 characterized by first producing the uneven surface by electrochemical machining using an electrode having a passage for electrolyte which passage causes the presence of a protuberance on the surface.

Patentansprüche

1. Elektrode (26) zur elektrochemischen Bearbeitung, bestehend aus einem leitfähigen Körper mit einem inneren Teil (34, 36), der zum Fördern von Elektrolyt zur Spitze der Elektrode ausgebildet ist, und mit einem leitfähigen Verschluss (32), der die Spitze der Elektrode (26) bedeckt, wobei der Verschluss (32) dem Elektrolyt gestattet, aus dem inneren Teil (34, 36) zu dem äußeren Teil der Elektrode (26) zu fließen, wobei der Verschluss (32) mehrere Durchgangslöcher mit weniger als 400 µm Auslaßdurchmesser hat und die Durchflußquerschnittsfläche der Lochauslässe an der äußeren Oberfläche des Verschlusses (32) kleiner als 50% der Querschnittsfläche des Verschlusses (32) ist, dadurch gekennzeichnet, daß der Verschluss (32) aus einem porösen Pulvermaterial besteht und daß der Verschluss (32) einen Durchsatz in dem Bereich von 3—8 ml/s/cm² hat, wenn der Druckabfall an dem Verschluss (32) in dem Bereich von 2,5—7,5 kPa ist.
2. Elektrode nach Anspruch 1, dadurch gekennzeichnet, daß der Verschluss (32) ein Sinterpulvermetallverschluss ist.
3. Elektrode nach Anspruch 1, gekennzeichnet durch einen Pulvermetallverschluss (32), der eine Filtrationsnennleistung von 20—100 µm hat.
4. Verfahren zur elektrochemischen Bearbeitung eines Werkstückes, um von diesem Material gleichmäßig abzutragen, unter Verwendung einer Elektrode, die einen leitfähigen Körper mit einem inneren Teil (34, 36), der zum Fördern von Elektrolyt zu der Spitze der Elektrode ausgebildet ist, und einen leitfähigen Verschluss (32) aufweist, der die Spitze der Elektrode (26) bedeckt, wobei der Verschluss (32) dem Elektrolyt gestattet, aus dem inneren Teil (34, 36) zu dem äußeren Teil der Elektrode (26) zu fließen, wobei der Verschluss (32) mehrere Durchgangslöcher mit weniger als 400 µm Auslaßdurchmesser hat und die Durchflußquerschnittsfläche der Lochauslässe an der äußeren Oberfläche des Verschlusses (32) kleiner als 50% der Querschnittsfläche des Verschlusses (32) ist, wobei die Elektrode (26) eine Arbeitsfläche (28) hat, die durch einen Spalt G von der Werkstückoberfläche (16) getrennt ist, wobei der Elektrolyt unter Druck durch die Elektrodenarbeitsfläche (26) und dann durch den Spalt G geleitet wird, wobei der Elektrolyt durch mehrere kleine Durchlässe fließt, die über die Arbeitsfläche (28) verteilt sind, dadurch gekennzeichnet, daß das Fließen des Elektrolyts durch die Arbeitsfläche des Verschlusses (32) hindurch erfolgt, der aus porösem Pulvermaterial besteht, wobei der Verschluss (32) einen Durchsatz in dem Bereich von 3—8 ml/s/cm² hat, wenn der Druckabfall an dem Verschluss (32) in dem Bereich von 2,5—7,5 kPa ist, wobei der Druckabfall des Elektrolyts an dem Teil der Elektrode (26), der die Arbeitsfläche (28) aufweist, größer ist als der Druckabfall des Elektrolyts in dem Spalt G und wobei die Werkstückoberfläche (16) aus einem Verbundmaterial besteht, das aus einem keramischen Teilchenmaterial in einer Metallmatrix besteht.

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2. The electrode according to claim 1 characterized in that the closure (32) is a sintered powder metal closure.
3. The electrode according to claim 1 characterized by a powder metal closure (32) having a filtration rating of 20—100 micrometers.
4. The process of electrochemically machining a workpiece to remove material uniformly therefrom, in utilizing an electrode comprised of a conductive body having an interior portion (34, 36) shaped for conveying electrolyte to the tip of the electrode and a conductive closure (32) covering the tip of the electrode (26), the closure (32) allowing electrolyte to flow from the interior portion (34, 36) to the exterior portion of the electrode (26), the closure (32) having a plurality of through holes of less than 400 micrometer exit diameter and the cross-sectional flow area of the hole exits at the exterior surface of the closure (32) being less than 50 percent of the cross-sectional area of the closure (32), wherein said electrode (26) has a working face (28) spaced apart by a gap G from the workpiece surface (16), electrolyte is flowed under pressure through the electrode working face (26) and then through the gap G flowing the electrolyte through a plurality of small passages distributed over said working face (28), characterized in that said flowing of the electrolyte is made through the working surface of said closure (32) made of a porous powder material, said closure (32) having a flow rate in the range of 3—8 ml/sec/cm² when the pressure drop across said closure (32) is in the range of 2.5—7.5 kPa, the pressure drop of the electrolyte through the portion of the electrode (26) which comprises the working face (28) being greater than the pressure drop of the electrolyte within the gap G, the workpiece surface (16) being made of a composite material comprised of a ceramic particulate in a metal matrix.
5. The method according to claim 4 characterized in that the pressure drop through the working face (28) portion is more than two times the drop within the gap G.
6. The method according to claim 4 characterized by disposing the working face (28) of the electrode (26) vertically upward, and placing the workpiece surface (16) being machined vertically above the working face (28), so that electrolyte issuing from the gap G flows away from the workpiece.
7. The method according to claim 4 characterized in that the porous metal is powder metal filter element material having a filtration rating in the range of 20—100 micrometers.
8. The method of electrochemically machining an uneven surface to produce a more even surface characterized by using the process of claims 4—9.
9. The method of claim 10 characterized by first producing the uneven surface by electrochemical machining using an electrode having a passage for electrolyte which passage causes the presence of a protuberance on the surface.

Patentansprüche

1. Elektrode (26) zur elektrochemischen Bearbeitung, bestehend aus einem leitfähigen Körper mit einem inneren Teil (34, 36), der zum Fördern von Elektrolyt zur Spitze der Elektrode ausgebildet ist, und mit einem leitfähigen Verschluss (32), der die Spitze der Elektrode (26) bedeckt, wobei der Verschluss (32) dem Elektrolyt gestattet, aus dem inneren Teil (34, 36) zu dem äußeren Teil der Elektrode (26) zu fließen, wobei der Verschluss (32) mehrere Durchgangslöcher mit weniger als 400 µm Auslaßdurchmesser hat und die Durchflußquerschnittsfläche der Lochauslässe an der äußeren Oberfläche des Verschlusses (32) kleiner als 50% der Querschnittsfläche des Verschlusses (32) ist, dadurch gekennzeichnet, daß der Verschluss (32) aus einem porösen Pulvermaterial besteht und daß der Verschluss (32) einen Durchsatz in dem Bereich von 3—8 ml/s/cm² hat, wenn der Druckabfall an dem Verschluss (32) in dem Bereich von 2,5—7,5 kPa ist.
2. Elektrode nach Anspruch 1, dadurch gekennzeichnet, daß der Verschluss (32) ein Sinterpulvermetallverschluss ist.
3. Elektrode nach Anspruch 1, gekennzeichnet durch einen Pulvermetallverschluss (32), der eine Filtrationsnennleistung von 20—100 µm hat.
4. Verfahren zur elektrochemischen Bearbeitung eines Werkstückes, um von diesem Material gleichmäßig abzutragen, unter Verwendung einer Elektrode, die einen leitfähigen Körper mit einem inneren Teil (34, 36), der zum Fördern von Elektrolyt zu der Spitze der Elektrode ausgebildet ist, und einen leitfähigen Verschluss (32) aufweist, der die Spitze der Elektrode (26) bedeckt, wobei der Verschluss (32) dem Elektrolyt gestattet, aus dem inneren Teil (34, 36) zu dem äußeren Teil der Elektrode (26) zu fließen, wobei der Verschluss (32) mehrere Durchgangslöcher mit weniger als 400 µm Auslaßdurchmesser hat und die Durchflußquerschnittsfläche der Lochauslässe an der äußeren Oberfläche des Verschlusses (32) kleiner als 50% der Querschnittsfläche des Verschlusses (32) ist, wobei die Elektrode (26) eine Arbeitsfläche (28) hat, die durch einen Spalt G von der Werkstückoberfläche (16) getrennt ist, wobei der Elektrolyt unter Druck durch die Elektrodenarbeitsfläche (26) und dann durch den Spalt G geleitet wird, wobei der Elektrolyt durch mehrere kleine Durchlässe fließt, die über die Arbeitsfläche (28) verteilt sind, dadurch gekennzeichnet, daß das Fließen des Elektrolyts durch die Arbeitsfläche des Verschlusses (32) hindurch erfolgt, der aus porösem Pulvermaterial besteht, wobei der Verschluss (32) einen Durchsatz in dem Bereich von 3—8 ml/s/cm² hat, wenn der Druckabfall an dem Verschluss (32) in dem Bereich von 2,5—7,5 kPa ist, wobei der Druckabfall des Elektrolyts an dem Teil der Elektrode (26), der die Arbeitsfläche (28) aufweist, größer ist als der Druckabfall des Elektrolyts in dem Spalt G und wobei die Werkstückoberfläche (16) aus einem Verbundmaterial besteht, das aus einem keramischen Teilchenmaterial in einer Metallmatrix besteht.



5. Verfahren nach Anspruch 4, dadurch gekennzeichnet, daß der Druckabfall an der Arbeitsfläche (28) mehr als das Doppelte des Druckabfalls in dem Spalt G beträgt.

6. Verfahren nach Anspruch 4, gekennzeichnet durch Anordnen der Arbeitsfläche (28) der Elektrode (26) vertikal aufwärts und Plazieren der Werkstückoberfläche (16), die bearbeitet wird, vertikal über der Arbeitsfläche (28), so daß der Elektrolyt, der aus dem Spalt G austritt, von dem Werkstück wegfleßt.

7. Verfahren nach Anspruch 4, dadurch gekennzeichnet, daß das poröse Metall Pulvermetallfilterelementmaterial ist, das eine Filtrationsnennleistung in dem Bereich von 20—100 µm hat.

8. Verfahren zum elektrochemischen Bearbeiten einer unebenen Oberfläche, um eine ebenere Oberfläche herzustellen, gekennzeichnet durch Verwendung des Verfahrens nach den Ansprüchen 4—7.

9. Verfahren nach Anspruch 8, dadurch gekennzeichnet, daß zuerst die unebene Oberfläche durch elektrochemische Bearbeitung und Verwendung einer Elektrode hergestellt wird, die einen Durchlaß für Elektrolyt hat, wobei der Durchlaß das Vorhandensein eines Vorsprungs auf der Oberfläche verursacht.

15 Revendications

1. Electrode (26) pour l'usinage électrochimique, cette électrode étant constituée d'un corps conducteur ayant une partie intérieure (34, 36) configurée pour transporter un électrolyte vers la tête de l'électrode, ainsi qu'une fermeture conductrice (32) recouvrant la tête de l'électrode (26), cette fermeture (32) permettant, à l'électrolyte, de s'écouler de la partie intérieure (34, 36) vers la partie extérieure de l'électrode (26), la fermeture (32) comportant plusieurs trous de part en part d'un diamètre de sortie de moins de 400 micromètres, tandis que la section transversale d'écoulement des sorties des trous à la surface extérieure de la fermeture (32) est inférieure à 50% de la section transversale de la fermeture (32), caractérisée en ce que cette fermeture (32) est réalisée en une matière en poudre poreuse, tandis qu'elle assure un débit se situant dans l'intervalle allant de 3 à 8 ml/seconde/cm² lorsque la perte de charge ayant lieu au travers se situe dans l'intervalle allant de 2,5 à 7,5 kPa.

2. Electrode selon la revendication 1, caractérisé en ce que la fermeture (32) est une fermeture constituée d'un métal en poudre fritté.

3. Electrode selon la revendication 1, caractérisée en ce qu'elle comporte une fermeture en métal en poudre (32) ayant une valeur nominale de filtration de 20—100 micromètres.

4. Procédé d'usinage électrochimique d'une pièce de travail en vue d'en enlever uniformément de la matière en utilisant une électrode constituée d'un corps conducteur ayant une partie intérieure (34, 36) configurée pour acheminer un électrolyte vers la tête de l'électrode, ainsi qu'une fermeture conductrice (32) recouvrant la tête de l'électrode (26), la fermeture (32) permettant à l'électrolyte, de s'écouler de la partie intérieure (34, 36) vers la partie extérieure de l'électrode (26), cette fermeture (32) comportant plusieurs trous de part en part d'un diamètre de sortie de moins de 400 micromètres, tandis que la section transversale d'écoulement des sorties des trous situées à la surface extérieure de la fermeture (32) est inférieure à 50% de la section transversale de la fermeture (32), l'électrode (26) ayant une face de travail (28) écartée d'un espace G de la surface (16) de la pièce de travail, l'électrolyte s'écoulant sous pression à travers la face de travail (26) de l'électrode, puis à travers l'espace libre G, l'électrolyte s'écoulant à travers plusieurs petits passages répartis sur la surface de travail précitée (28), caractérisé en ce que l'écoulement de l'électrolyte a lieu à travers la surface de travail de la fermeture (32) réalisée en une matière en poudre poreuse, cette fermeture (32) assurant un débit se situant dans l'intervalle allant de 3 à 8 ml/seconde/cm² lorsque la perte de charge en travers de cette fermeture (32) est située dans l'intervalle allant de 2,5 à 7,5 kPa, la perte de charge de l'électrolyte à travers la partie de l'électrode (26), qui constitue la face de travail (28), étant supérieure à la perte de charge de l'électrolyte à l'intérieur de l'espace G, la surface (16) de la pièce de travail étant constituée d'une matière composite comprenant des particules d'une matière céramique dans une matrice de métal.

5. Procédé selon la revendication 4, caractérisé en ce que la perte de charge se produisant à travers la partie formant la face de travail (28) est supérieure à deux fois la perte de charge se produisant à l'intérieur de l'espace libre G.

6. Procédé selon la revendication 4, caractérisé en ce qu'on dispose la face de travail (28) de l'électrode (26) verticalement vers le haut, tandis que l'on place la surface (16) de la pièce de travail à usiner verticalement au-dessus de la face de travail (28), de telle sorte que l'électrolyte sortant de l'espace G s'écoule à l'écart de la pièce de travail.

7. Procédé selon la revendication 4, caractérisé en ce que le métal poreux est une matière pour éléments filtrants en métal en poudre ayant une valeur nominale de filtration se situant dans l'intervalle allant de 20 à 100 micromètres.

8. Procédé d'usinage électrochimique d'une surface inégale en vue d'obtenir une surface plus uniforme, caractérisé en ce qu'on adopte le procédé selon les revendications 4 à 7.

9. Procédé selon la revendication 8, caractérisé en ce qu'on forme tout d'abord la surface inégale par usinage électrochimique en utilisant une électrode comportant un passage pour l'électrolyte, ce passage donnant lieu à la présence d'une protubérance sur la surface précitée.

