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COMBINED PLATING AND HONING METHOD AND APPARATUS

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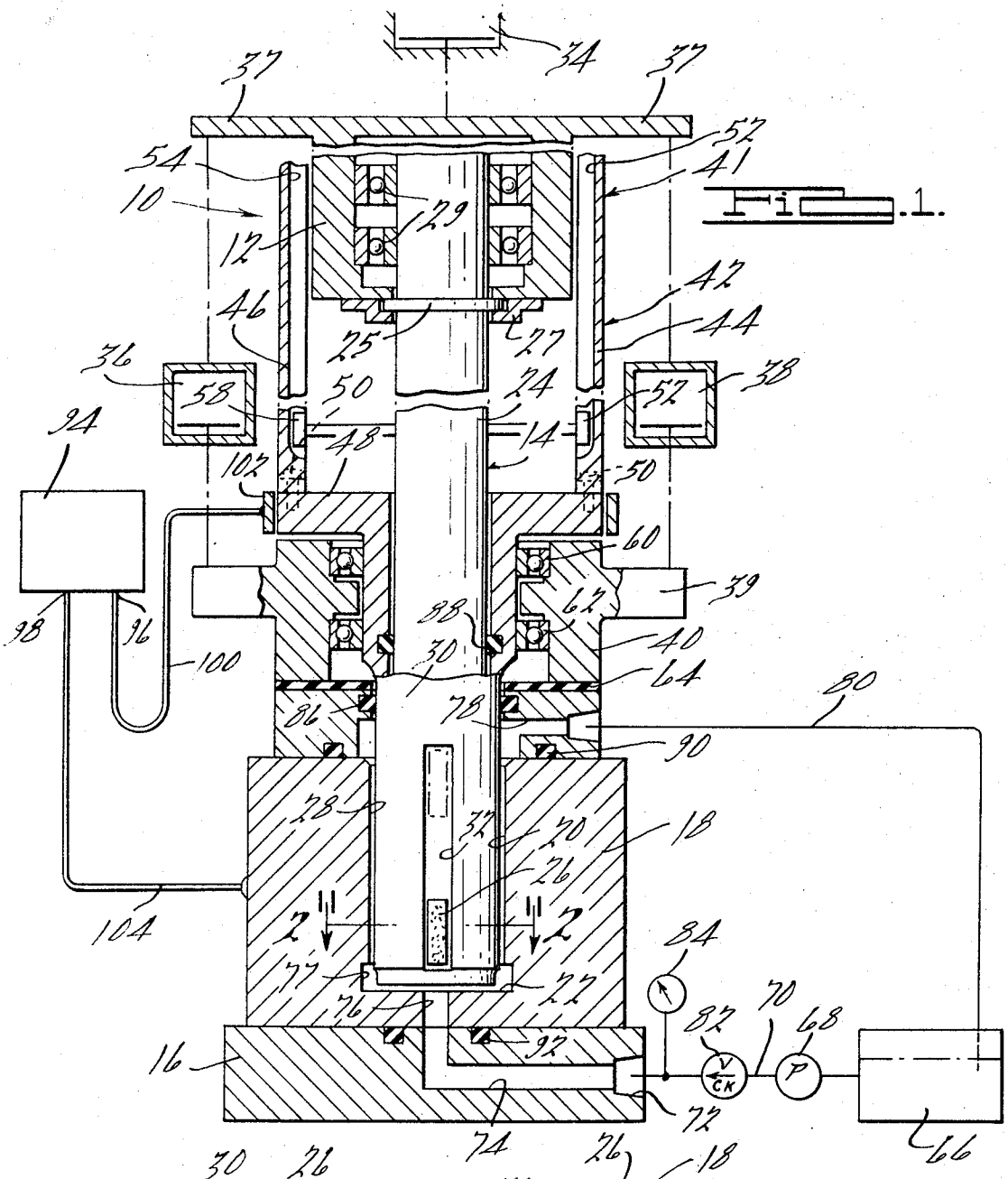

Fig. 1.

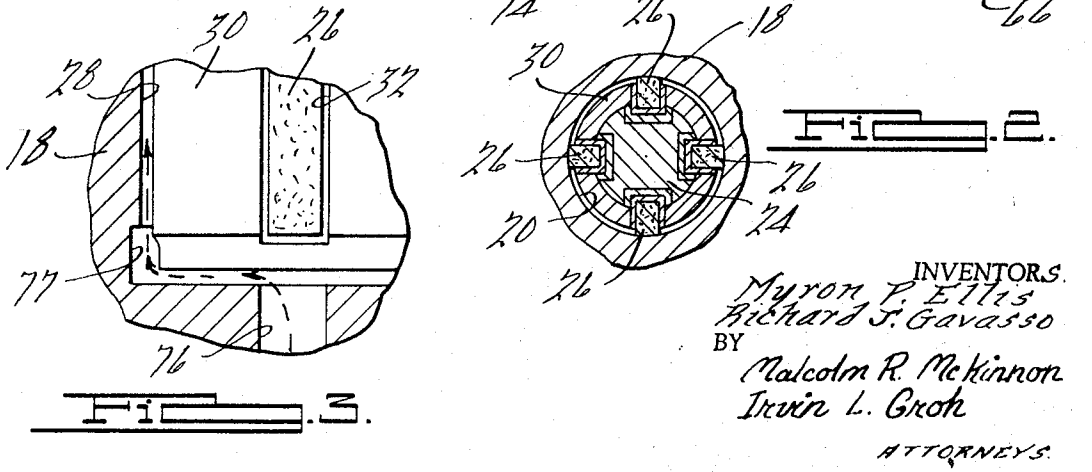

Fig. 2.

Fig. 3.

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COMBINED PLATING AND HONING METHOD AND APPARATUS

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U.S. Cl. 204—26 6 Claims

ABSTRACT OF THE DISCLOSURE

A combined plating and honing method and apparatus utilizing and incorporating a rotatable sleeve type anode and a plurality of honing stones mounted for coaxial rotation with and reciprocation relative to the sleeve type anode, the anode being rotatable relative to a cathodic work surface to effect plating thereon and the honing stones being movable into engagement with the plated surface to simultaneously and/or sequentially mechanically hone such surface.

BRIEF SUMMARY OF THE INVENTION

This invention relates to the plating and honing arts and, more particularly, to an improved combined plating and honing method and apparatus effective to plate a surface of a workpiece and simultaneously and/or sequentially mechanically hone such surface so as to provide an improved plated and honed workpiece having an improved surface finish.

Heretofore, various methods and apparatus have been utilized for the purpose of plating and simultaneously honing the surface of a workpiece. For example, various methods and apparatus have been provided for simultaneously burnishing and plating a surface of a workpiece while the workpiece is immersed in a plating solution and the workpiece is functioning as an electrical cathode while the honing tool is functioning as an electrical anode. For example, such methods and apparatus of the indicated character are disclosed in the U.S. applications of Myron P. Ellis and Richard J. Gavasso Ser. No. 838,113 filed July 1, 1969 now Pat. No. 3,616,289, and Ser. No. 864,086 filed Oct. 6, 1969 now Pat. No. 3,637,469, and both entitled "Electroplate Honing Method."

An object of the present invention is to overcome disadvantages in prior plating and honing methods and apparatus of the indicated character and to provide an improved combined plating and honing method and apparatus utilizing a rotatable sleeve type anode, positionable in very close proximity to the workpiece surface, and a plurality of honing stones mounted for coaxial rotation with and reciprocation relative to the sleeve type anode, the anode being rotatable relative to the workpiece surface to effect the plating thereof, and the honing stones being movable into engagement with the plated surface to simultaneously mechanically hone such surface during the plating operation, the workpiece surface being exposed to a pressurized conventional plating solution during the plating and honing operation.

Another object of the invention is to provide an improved plating and honing method and improved plating and honing apparatus that are economical and commercially feasible to practice and manufacture, durable, efficient and reliable in operation.

In accordance with the present invention, an improved honing method and improved apparatus are provided, the improved method utilizing the improved apparatus which includes a honing tool that is mounted for coaxial rotation with and reciprocation relative to a sleeve type anode, the honing tool carrying a plurality of honing

stones projectable beyond the periphery of the sleeve type anode and into engagement with the workpiece surface. The sleeve type anode is disposed in very close but spaced relationship with respect to the surface of the workpiece and in such manner that the sleeve acts as an electrical anode and the workpiece as an electrical cathode, and during high current density electroplating, an electrolyte is circulated between the sleeve and the workpiece whereby metal is deposited on the surface of the workpiece. The sleeve type anode is normally held in an axially fixed position relative to the work surface and rotated during the plating operation while the honing tool is rotated coaxially with the sleeve type anode and simultaneously reciprocated during the plating operation so as to provide an improved plated and honed surface having surface characteristics superior to those heretofore obtainable. The improved honing method and apparatus may also be utilized to electroplate and simultaneously hone a semi-blind or stepped bore as well as a straight cylindrical bore.

The above as well as other objects and advantages of the present invention will become apparent from the following description, the appended claims and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic, elevational view, with portions in cross-section, of a combined honing and plating machine embodying the present invention;

FIG. 2 is a cross-sectional view of the structure illustrated in FIG. 1, taken on the line 2—2 thereof; and

FIG. 3 is a fragmentary, enlarged elevational view of a portion of the structure illustrated in FIG. 1.

DETAILED DESCRIPTION

Referring to the drawings, the present invention is illustrated embodied in apparatus for honing and plating stepped or semi-blind end and straight cylindrical bores of a workpiece although it will be understood that the present invention is applicable to other uses. FIG. 1 illustrates a honing machine, generally designated **10**, having a reciprocating quill **12** to which a honing and plating tool, generally designated **14**, is drivably connected for reciprocation with the quill **12** and rotation relative to the quill **12**. A work holding fixture **16** is provided which is mounted beneath the tool **14** as illustrated in FIG. 1 and supports a workpiece **18** in axial alignment with the tool **14**.

Details of an electrochemical honing machine of a type in which the present invention may be incorporated are more fully disclosed in U.S. Pat. No. 3,390,068 issued to M. P. Ellis et al. on June 25, 1968. It will be understood that a wide variety of honing tools may be mounted to the reciprocating quill **12** for both reciprocating and rotational movement in any manner well known in the art.

As shown in FIG. 1, the honing and plating tool **14** is positioned relative to the workpiece **18** for combined plating and honing, the workpiece **18** being disposed in a fixed position relative to the fixture **16** forming a part of the machine **10**. The illustrated workpiece **18** has a stepped bore **20** in which the lower portion of the bore is partially closed, as at **22**. Such a bore may be described generally as a modified blind bore but it will be understood that the present invention may also be utilized with straight cylindrical bores.

The combined honing and plating tool **14** comprises a tool support **24** which includes a plurality of honing stones **26**, four of such stones **26** being illustrated although any desired number of such honing stones may be utilized. The stones **26** are mounted relative to the

tool support **24** so that they may be adjusted radially outwardly or inwardly relative to the axis of rotation of the tool support in any manner well known in the art whereby the stones may be moved toward and away from the bore surface which is to be plated and honed. One means for moving the honing stones **26** and for supporting them on the tool support **24** is more fully disclosed in the aforementioned Ellis patent and in U.S. Pat. No. Re. 26,499 issued to J. H. Greening on Dec. 3, 1968. It will be understood that any other suitable means may be employed to support and move the honing stones.

In the embodiment of the invention illustrated, the tool support **24** includes an integral flange **25** which is secured to the quill **12** by a retaining ring **27** whereby the tool support reciprocates with the quill **12**, and the tool support **24** is supported for rotation within the quill **12** by bearings such as **29**.

Surrounding the honing tool support **24** is a sleeve member **30** which is also adapted to project into the bore **20**. The sleeve **30** is provided with longitudinally extending slots **32** adapted to receive the honing stones **26** so that upon radial adjustment, the stones may protrude through the slots **32** and into engagement with the bore surface **28** with any desired surface pressure or they may be retracted out of engagement with the surface **28**. The inside diameter of the sleeve member **30** affords sufficient clearance between the sleeve and the honing tool support **24** to permit reciprocation or relative movement of the tool support relative to the sleeve member **30**. The outside diameter of the sleeve member is of a selected size to afford a small clearance with the wall surface **28** of the bore **20** in the workpiece **18**.

As schematically shown in FIG. 1, the quill **12** is adapted to be reciprocated by a conventional piston and cylinder unit **34** mounted on the machine **10** while the sleeve member **30** is adapted to be releasably clamped to the quill **12** through the agency of conventional piston and cylinder units **36** and **38** for selective reciprocation with the tool support **24**. The pistons of the piston and cylinder units **36** and **38** are connected to a flange **39** provided on a bearing collar **40** which supports the sleeve **30** while the cylinders of the piston and cylinder units **36** and **38** are connected to the opposite ends of an outwardly projecting arm **37** fixed to the quill **12**. A rotatable drive mechanism, generally designated **41**, is also provided for simultaneously rotating the tool support **24** and the sleeve **30**. The rotatable drive mechanism **41** is comprised of a driving cage **42** which may be rotated about the axis of the quill **12** by any suitable rotating driving mechanism such as a splined gear drive (not shown). The cage **42** includes angularly spaced, vertically extending driving members, such as **44** and **46**, the lower end portions of which are fixed to an integral flange **48** provided on the sleeve **30**, as by bolts **50**, while the upper end portions of the driving members **44** and **46** are driven by the aforementioned driving mechanism. The driving members **44** and **46** define longitudinally extending slots **52** and **54**, respectively, in which are mounted rollers, such as **56** and **58**, the rollers **56** and **58** in turn being fixed to the tool support **24**. With such a construction, rotation of the drive members **44** and **46** imparts simultaneous rotation to both the tool support **24** and the sleeve **30**, the sleeve **30** being supported for rotation by bearings **60** and **62** carried by the bearing collar **40**. In addition, the tool support **24** is permitted to be reciprocated independently of the sleeve **30** through the agency of the piston and cylinder unit **34** and the sleeve **30** is permitted to be reciprocated with the tool support **24** by actuating the piston and cylinder units **36** and **38** so that the arm **37**, the flange **48** of the sleeve **30** and the bearing collar **40** are clamped together for reciprocation with the quill **12**. Thus, such a construction either permits the rotating tool support **24** to move vertically relative to the simultaneously rotating but longitudinally stationary sleeve **30** within the range afforded by the length of the slots **32**, or both the tool support **24** and sleeve **30** may be simultaneously reciprocated.

The lower end of the collar **40** is insulated from the fixture **16** by an insulator **64** made of any suitable electrically non-conductive material, the insulator **64** remaining stationary relative to the fixture **16** while permitting rotational and reciprocable movement of the sleeve member **30**.

As is well known, it is necessary during plating to provide an electrolyte or plating solution in the area between the tool and the work surface to be plated. As shown in FIG. 1, the flow path or circuit by which plating solution may be circulated, includes a reservoir **66** of electrolytic solution which is pumped by means of a pump **68** through a conduit **70** to a port **72** in the fixture **16** and thereafter through passage **74** into the lower end **76** at the semi-blind bore **20**. The plating solution is free to flow through the enlarged radial bore portion **77** and through the annular space formed by the outer diameter of the sleeve member **30** and the bore surface **28** of the workpiece to a passageway **78** provided at the upper end of the fixure **16**. The plating solution flows from the passageway **78** through a conduit **80** which returns the plating solution to the reservoir **66**. In order to prevent reverse flow through the system, a check valve **82** is provided in the conduit **70** and a pressure gauge **84** may be provided if desired.

In order to seal the plating solution within the system, a seal **86** is provided at the upper end of the fixture **16** for engagement with the outside diameter of the rotating sleeve member **30**. Another seal **88** is provided which is located between the inner diameter of the sleeve member and the outer diameter of the tool support **24**. A static seal **90** is also provided between the stationary fixture **16** and the upper surface of the workpiece **18** while the lower portion of the workpiece is sealed relative to the supporting fixture by means of the seal **92**.

The plating solution acts to form an electrically conductive path between the electrically conductive sleeve member **30** and the electrically conductive workpiece **18**. As shown in FIG. 1, a power supply **94** of direct current is provided adjacent the honing machine **10** and is provided with positive and negative output terminals **96** and **98**. The power supply unit functions to supply direct electric current of a selected magnitude to the work environment. The positive output terminal **96** is connected by a conductor **100** to a brush take-off unit **102** by means of which the electric current may be transmitted between the power source and the sleeve member **30** during rotation of the latter. From the sleeve member, the current flows through the electrolyte to the workpiece **18** which is of electrically conductive material. A conductor **104** between the workpiece and the negative terminal of the power supply unit completes the electrical circuit.

Thus far the invention has been described in connection with operations on a workpiece with a modified blind bore. It will be understood, however, that the invention may be employed to hone and plate an open ended or straight cylindrical bore in a workpiece. In this instance, the fixture may be provided with an enlarged inlet passageway to eliminate any restriction to the free flow of plating solution into the bore of the workpiece during the plating and honing process.

In operation, the apparatus **10** is employed for honing and electroplating by first retracting the quill **12** together with the honing-plate tool **14** to its uppermost position. A workpiece **18** is then positioned in the fixture **16** so that the workpiece bore **20** is in axial alignment with the axis of rotation of the tool **14**. With the honing stones **26** retracted within the slots **32** of the sleeve member **30**, the tool support **24** and sleeve member **30** are moved as a unit vertically downward until the lower end of the sleeve **30** is located at a position near the lower end of the modified stepped bore as shown in FIGS. 1 and 2 after which the sleeve **30** is unclamped from the quill **12**

by releasing the piston and cylinder units **36** and **38**. With the combined honing and plating tool **14** in this position, the flow of plating solution is initiated to cause fluid flow between the outer surface of the sleeve member **30** and the bore surface **28** of the workpiece. Thereafter, the honing stones are brought into engagement with the surface **28** and the tool support **24** is reciprocated by the piston and cylinder unit **34** and both the tool support **24** and sleeve **30** are rotated through the agency of the drive mechanism **41** to cause an abrading action to take place between the honing stones and the work surface. After a desired degree of abrading has taken place, the work surface will be sufficiently clean and be prepared for the subsequent plating cycle.

Thereafter, the electrical current is initiated so that the sleeve **30** acts as an anode and the workpiece acts as a cathode and a plating cycle is accomplished during continued rotation of the sleeve member **30** but with the honing stones **26** retracted slightly to relieve the pressure on the work surface of the workpiece. Under these conditions and with the continued flow of plating solution, plating of the surface **28** is effected. It will be understood that the D.C. current flows in the electrical circuit previously described and particularly between the sleeve member **30** which acts as an anode, through the electrolyte to the workpiece which acts as a cathode. As is well known, this causes a depositing of the plating material on the surface **28** of the workpiece. After a sufficient period of time and sufficient depositing and honing of plating material on the work surface **28** of the workpiece, the electrical current flow may be terminated. If desired, honing may be continued after the flow of electrical current is terminated.

While preferred embodiments of the invention have been illustrated and described, it will be understood that various changes and modifications may be made without departing from the spirit of the invention.

What is claimed is:

1. A method of finishing a surface of an electrically conductive cathodic workpiece with tool means having an electrically conductive anodic sleeve portion and an abrasive member supported by the tool means and adjustable outwardly relative to said sleeve portion comprising the steps of positioning said anodic sleeve portion in predetermined spaced relationship with respect to the cathodic workpiece, flowing a plating solution between said surface and said electrically conductive cathodic sleeve portion, passing a direct electrical current between said sleeve portion and said surface through said plating solution to apply metal electrochemically to said surface, simultaneously rotating said tool means and said sleeve portion and reciprocating said tool means independently of said sleeve portion so that the metal on said surface is abraded, terminating the supply of electrical current, and retracting said tool means and sleeve portion from said workpiece.

2. In plating and honing apparatus for plating metal on and removing metal from a surface defining a bore in an electrically conductive cathodic workpiece, the combination comprising honing tool means supported for rotational and reciprocable movement, means for supporting an electrically conductive cathodic workpiece defining a bore coaxially aligned with the longitudinal axis of said honing tool means, an anodic sleeve member surrounding said honing tool means and adapted for positioning in closely spaced relationship to said surface defining said bore, said sleeve member being provided with at least one longitudinally extending slot, abrasive means supported on said tool means and projecting through said slot for movement radially relative to the axis of said tool means into and out of abrading engagement with said bore surface, means for flowing a plating solution between said sleeve member and said bore surface, means for moving said abrasive means over said bore surface in a combined reciprocating and rotating motion to remove metal mechanically from said bore surface, means for moving said sleeve member longitudinally in said bore and for maintaining said sleeve member in a fixed longitudinally position in said bore during rotation of said sleeve member, means for passing a direct electric current between said sleeve member to said bore surface through said plating solution, and means for terminating the supply of direct electric current at the completion of the work cycle.

3. In a combined plating and honing apparatus for removing and plating metal on a surface defining a bore in an electrically conductive cathodic workpiece, the combination comprising a honing tool, an anodic sleeve formed of electrically conductive material surrounding said tool and defining at least one elongated slot, said sleeve being adapted for positioning in spaced relationship to a workpiece, abrasive means mounted on said honing tool and projecting through said slot for abrading engagement with said bore surface of said workpiece, means for flowing a plating solution between said sleeve and said bore surface of said workpiece, means for simultaneously rotating said sleeve and said abrasive, means for moving said abrasive means in a reciprocating motion independently of said sleeve to remove metal mechanically from said bore surface, means for passing a direct electric current between said anodic sleeve and said bore surface through said plating solution to apply plating materials to said bore surface, means for terminating the supply of direct electric current when the bore of said workpiece has been plated to the desired size, and means for simultaneously retracting said honing tool and sleeve at the end of the plating cycle.

4. A combined plating and honing apparatus as defined in claim **3** including means for simultaneously rotating said honing tool and sleeve, and means for reciprocating said honing tool and sleeve.

5. A combined plating and honing apparatus as defined in claim **3**, wherein said means for passing a direct electric current between said sleeve and said bore surface includes means for connecting said workpiece to one electrical terminal and said sleeve to the other electrical terminal of a direct electric current power supply.

6. In combined plating and honing apparatus for removing and plating metal on a surface defining a bore in an electrically conductive workpiece, the combination comprising a honing tool means including a sleeve member having an electrically conductive surface, means for supporting an electrically conductive workpiece with a bore surface in a position with the longitudinal axis of the bore coaxially aligned with the longitudinal axis of said sleeve member, abrasive means on said tool means adapted for abrading engagement with said bore surface, means for flowing a plating solution between said sleeve member and said bore surface, means for rotating said tool means and reciprocating said abrasive means independently of said sleeve member while said abrasive means is in contact with said bore surface, means for passing a direct electric current between said sleeve member and said bore surface through said plating solution whereby said workpiece is renderd cathodic and said sleeve member is rendered anodic, means for terminating the supply of direct electric current when the bore has been plated to the desired size, and means for simultaneously retracting the tool means and sleeve including the abrasive means.

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