[54] METHOD AND APPARATUS FOR ACTIVATION OF AN ABRASIVE SLURRY BY AN ELECTRIC ARC

[75] Inventor: Carl E. Kimmelmann, White Twp., Warren County, N.J.

[73] Assignee: David B. Braelow, West Orange, N.J.; a part interest

[22] Filed: Apr. 8, 1974

[21] Appl. No.: 459,080

[52] U.S. Cl. 219/68, 51/7, 51/26, 51/317, 219/76

[51] Int. Cl. B23p 1/00

[58] Field of Search 51/7, 26, 317; 219/68, 219/76

References Cited
UNITED STATES PATENTS
2,850,854 9/1958 Levy 51/317
2,974,215 3/1961 Inoue 219/68
3,277,267 10/1966 Blaszkowski 219/76

3,423,880 1/1969 Hershler 51/7
3,523,834 8/1970 Hewins 219/68 X

Primary Examiner—J. V. Truhe
Assistant Examiner—N. D. Herkamp
Attorney, Agent, or Firm—Popper, Bain, Bobis, Gilfillan & Rhodes

[57] ABSTRACT

The method of reducing the surface of a body by applying an abrasive slurry to the portion of the surface of the body to be reduced and forming successive electric arcs at the portion of the surface to be reduced, to drive the abrasive slurry away from the portion and allow it to return to the portion in the interval between the successive arcs.

The apparatus for reducing the surface of a body wherein an abrasive slurry is maintained on the portion of the surface of the body to be reduced, and electric arcs are formed successively at the portion of the body to be reduced, whereby the slurry is driven away from the portion and returned and replenished between successive arcs.

16 Claims, 5 Drawing Figures
METHOD AND APPARATUS FOR ACTIVATION OF AN ABRASIVE SLURRY BY AN ELECTRIC ARC

BACKGROUND OF INVENTION

1. Field of Invention

This invention relates generally to the reduction of surfaces by abrasive slurries, and particularly to methods and apparatus wherein the abrasive slurry is activated by successive electrical arcs.

2. Description of Prior Art

The reduction of surfaces by electric arcs through the use of what is generally referred to as an electro-discharge machine (E.D.M.) is a well-known apparatus for conducting a well-known procedure wherein an arc between a conductive workpiece and an electrode or between two electrodes disposed closely adjacent to a surface to be reduced, will vaporize a portion of the surface, or will break a portion of the surface into small fragments. The result of practicing this method will reduce the surface but may cause an undesirably pitted surface. The material whose surface is reduced may be damaged by the heat of the arc, and will show cracks in microphotographs. Moreover, the surface may be overheated and lose as much as approximately 30 percent of its normal tensile strength. If holes are made by this electro-discharge method, they may have a rather coarse, mottled appearance due to the presence of numerous craters and cracks. The reduction of surfaces by electro-discharges is believed to be due in part to shock waves generated by the arc. In addition, the material of the surface may be heated and vaporized. Exotic materials may be severely impaired for they may melt under the heat of the arc, or microcracks may be formed.

If the reduction of surfaces by electro-discharge machine is undesirable because of the harmful side effects referred to, another method such as drilling with a bit may be resorted to. This procedure has its disadvantages because a hard steel bit used to make a hole 0.0015 inch in diameter is usually subject to frequent breaking of the bit. Not only is this a problem but retraction of the broken piece of the bit from the hole drilled may prove difficult; besides, the bit very quickly loses its sharpness. If the workpiece is of hi-chrome steel, hi-nickel steel especially tempered steel, or tungsten-carbide steel, the drilling may be even more difficult.

Even when conventional methods are used to reduce surfaces, the control of the size within acceptable tolerances is quite difficult and machine marks impair the smoothness of the surface of the workpiece so that a smooth finish is not obtained or must be obtained by separate procedures.

The application of an abrasive slurry to the drilling site does very little to improve the action of the bit.

SUMMARY OF INVENTION

It has been found that activating an abrasive slurry at the point or reduction by the application of an electric arc, can accomplish a rapid reduction of the surface, and produce a smooth, unpitted surface, without impairing the workpiece, by cracking or pitting it. The slurry is formed of a dielectric liquid medium carrying abrasive particles, and is maintained at the site where the surface of the workpiece is to be reduced. The passage of an electric arc between an electrode and the workpiece (if the workpiece is electrically conductive) or between two electrodes adjacent to the portion of the workpiece to be reduced, causes a disturbance in the abrasive slurry at the point of the arc where the surface reduction is desired to be accomplished. In so doing, the slurry is moved aside to permit the formation of an arc when the electric potential overcomes the resistance of the slurry. In so moving, the abrasive particles in the slurry arc carried with the slurry displaced by the arc, thereby moving to abrade the surface. Upon the cessation of the arc, the next arc is in a different position and the abrasive slurry will be displaced at that new location. It is believed that the particles may be moved by ultrasonic shock wave through the slurry and pressed against the surface. It is also believed that spatial displacement of the slurry by the arc is also accomplished. It is further believed that the arc may vaporize a portion of the surface to be reduced, perhaps softening it so that it yields more readily to the abrasives in the slurry. In any event, the surface is reduced with little or no evidence of pitting or cracking, and a relatively smooth area results.

An apparatus for producing a smooth bore in a workpiece involves the pumping of the abrasive slurry into the bore of the workpiece. When the workpiece is revolved and reciprocated an electrode intruded into the bore is energized with the workpiece so that electric arcs are successively formed between the workpiece and the electrode. A mirror-like bore is produced in the workpiece, generally devoid of any pits or cracks.

THE DRAWING

These objects and advantages as well as other objects and advantages are attained by the method practiced by the devices shown by way of illustration in the drawing in which:

FIG. 1 is a top plan view of an apparatus which forms successive electric arcs between an electrode and a workpiece at a point where an abrasive slurry is applied;

FIG. 2 is an enlarged partial sectional view of the workpiece and the electrode shown in FIG. 1;

FIG. 3 is circuit diagram of the apparatus for producing the arc;

FIG. 4 is a view of a modification of the apparatus which forms successive electric arcs between an electrode positioned adjacent to the surface of a flat conductive workpiece whose surface is to be reduced; and

FIG. 5 is a view of a modification of the apparatus which forms successive electric arcs between two electrodes disposed adjacent to the surface of a flat dielectric workpiece whose surface is to be reduced.

PREFERRED EMBODIMENT

Referring now to the drawings in detail, an abrasive slurry 11 is prepared from a dielectric liquid such as an oil having no flash point or a very high flash point. Ultrapure water may be used as the dielectric vehicle for the liquid slurry, but it soon loses its dielectric character. Once it becomes electrically conductive, it inhibits the arc formation by reason of condition of the electric impulses. It must then be replaced. On the other, oil is not readily rendered electrically conductive. Particles of garnet, sand, or pumice are mixed with the liquid.

The particles are preferably uniformly graded. Lanthanum or cerium oxide, diamond dust or other well known standard abrasives may be used. The ratio of the
liquid to the abrasive is preferably 1:10, but this ratio may be varied, depending upon the character of the workpiece, character of the abrasive, and the speed of reduction desired. A few simple tests will readily determine a proper ratio of liquid to abrasive, dependent upon the nature of the abrasives and the nature of the workpiece. The abrasive particles in the slurry may be in the range of 500 to 1,000 grit, again dependent upon the fineness of the finish desired, the character of the workpiece, and the character of the abrasive.

It may be necessary to use initially a rather coarse abrasive particle in the slurry to accomplish the rapid reduction of the surface, and later to finish off with a fine abrasive, in order to obtain the ultimate smooth finish.

The slurry is deposited in a tank provided with an agitator, driven by a motor. This insures the homogeneous character of the slurry-abrasive mixture. A conduit carries the slurry to a nozzle from which it is discharged into the bore of a workpiece. The gravitational discharge of the slurry from the nozzle may be sufficient, but a pump may be added to accomplish the forceable discharge of the slurry. The workpiece is held in a collet, mounted on a rotatable shaft. The shaft is mounted for rotation on bearings. A pulley on the shaft rotates it. An eccentric cam will reciprocate the shaft, and overcome a spring causing the shaft to reciprocate as it revolves.

An electrode is mounted at an angle of at least 1° to the bore in the workpiece. This insures the generation of an arc generally from the tip of the electrode, rather than from random points thereon. The electrode is held in a collet on the end of a rod. The rod is slidable mounted in a support block. The end of the rod extends through the block and carries a pin. A spring is compressed between the block and the pin and normally urges the electrode collet toward the block. A threaded shaft is mounted coaxially with the rod; a wheel is mounted on the threaded shaft and enables the advancing and retracting of the electrode to the desired location with respect to the bore in the workpiece. Thus when the gap between the electrode and the workpiece becomes so great as to inhibit arcing the wheel may be turned to bring the tip of the electrode closer to the workpiece, so that arcing will proceed uninhibited.

The arc generator is of conventional design, power being supplied by either standard direct current (pulse type), or rectifier-capacitor type. The conventional rectifier-capacitor type power supply is preferred but it should be modulated by a choke. A suitable arc generator circuit is shown in Fig. 3. A voltage regular provides suitable gap voltage to an isolation transformer. The secondary of the transformer is connected to a rectifier. The output of the rectifier is conducted to a group of capacitors in parallel. Switches can selectively connect the capacitors into the circuit, depending upon the arc potential desired. The capacitors may be in the range of 0.1 to 10 mfd. An indicator light is controlled by the switch to denote the charging condition of the capacitors. The capacitors discharge to the gap. One side of the discharge circuit is modulated by the variable resistance which is connected to the choke coil. A capacitor may be connected by the switch across the choke coil. When this switch is open, the arc will have its energy drastically reduced so that the possibility of cracking, burning, pitting, or melting at the point of discharge is eliminated. A voltmeter is indicated to measure the arc potential at discharge, so that if the voltage reaches so high a level that there is danger of cracking, etc., the voltage of the discharge may be reduced. It has been found that an arc discharge in the range of 100-400 V, will generally have no undesired effect in the workpiece. However, the arc voltage may be varied within wide limits depending upon the dielectric valve of the slurry, the gap distance, the material of the workpiece. None of these parameters can be predetermined but must be worked out by trial under the circumstances of operation, with due regard to the nature of the slurry, the gap distance, and the material of the workpiece.

Electrical energy is stored in the capacitors over a relatively short period of time and is discharged with sudden violence at the instant switch is effectively closed. The switch may be mechanically operated or may be an electronic device.

Many designs of arc generators, gaps and switches may be devised for different applications. The operating capacities and voltages may be varied widely but it is found that 60 to 400 volts with 0.001 microfarad across choke coil is acceptable. The circuit produced a spark sufficiently intense and of sufficiently short a duration so that it may activate the slurry as required.

A trigger circuit of conventional design may be used.

Shock waves are produced in air by a disturbance that is sufficiently strong and abrupt. Such shock waves are believed to be also produced in liquid media such as the abrasive slurry. The electric arcs travel at a speed probably close to the speed of light and generate shock waves which activate the slurry.

It is preferred that the arcs shall be generated at a rate of up to 100,000 pulses per second. The arc will displace the dielectric slurry in its path, moving the abrasive particles to the bore, causing it to be reduced smoothly without pitting and forming a slick surface. A continuous discharge of the slurry into the bore provides abrasive particles to erode the bore as the workpiece reciprocates over the electrode and as the workpiece revolves continuously.

This process can also be applied to reduce not only interior but exterior surfaces, such as cylindrical or flat shapes, as well as spherical, conical or three-dimensional curved surfaces; in such cases, the electrode, instead of being inserted into a cavity in the workpiece, is positioned instead adjacent to the exterior surface of the workpiece. Where flat surfaces are reduced, the rotation of the pulley is not required, but only the reciprocation of the collet is required, by the continuous operation of the cam. When the workpiece is dielectric material, additional electrodes are provided so that the arc is disposed close to the surface to be reduced.

For reducing flat surfaces, Fig. 4 illustrates a bracket substituted for the collet and the workpiece bolted or otherwise held in place. The nozzle is directed to apply the abrasive slurry to the flat surface of the workpiece. The angle of the electrode is adjusted to approximately 15° with respect to the workpiece. The pulley is not activated to rotate the workpiece but the cam is driven to reciprocate the
flat surface of the workpiece in one plane continuously as the arc activates the slurry flowing over the flat surface of the workpiece. In FIG. 5, a dielectric workpiece 53 is attached to the bracket 51. A double, dielectric electrode holder 54 is provided. Two electrodes 55, 55 are inserted in the electrode holder 54 and each is connected to the arc generator. The two electrodes are adjusted to closely approach the surface of the workpiece and the abrasive slurry 11 is fed to the surface of the workpiece 53. The pulley 22 is not activated, but the cam 23 is driven to reciprocate the flat surface of the dielectric workpiece 53. The arc formed between the two electrodes 55, 55 is sufficiently close as to activate the abrasive slurry at the surface of the dielectric workpiece 53, and to reduce and polish the surface thereof.

What is claimed:

1. A method for reducing a surface of a workpiece comprising:
   a. supplying a dielectric, abrasive slurry to a portion of a workpiece to be reduced;
   b. generating successive electric arcs in the slurry to move it at the portion of the workpiece to be reduced;
   c. reducing the surface of the workpiece by the movement of the abrasive slurry.

2. The method of claim 1 in which the electric arc is formed between an electrode and an electrically conductive workpiece.

3. The method of claim 1 in which the electric arc is formed between two electrodes immediately adjacent to the workpiece.

4. The method of claim 1 in which the slurry is oil and abrasive material.

5. The method of claim 1 in which the slurry is water and abrasive material.

6. The method of claim 1 in which the electric arcs are formed between the workpiece and electrode disposed in nonparallel relation to the workpiece surface.

7. The method of claim 1 in which the workpiece is rotated with respect to the electrode.

8. The method of claim 1 in which the workpiece is reciprocated with respect to the electrode.

9. The method of claim 1 in which the workpiece is reciprocated and rotated with respect to the electrode.

10. A method for reducing a surface of a workpiece comprising:
   a. supplying a dielectric, abrasive slurry to a portion of a workpiece;
   b. positioning an electrode in the slurry in spaced relation to the workpiece;
   c. generating successive arcs in the abrasive slurry between the electrode and the workpiece.

11. An apparatus for reducing the surface of a workpiece comprising:
   a. a means to hold a workpiece;
   b. an electrode disposed angularly in spaced relation to the workpiece;
   c. an abrasive slurry in the space between the electrode and the workpiece;
   d. a means to generate successively electric arcs between the electrode and the workpiece, in the slurry.

12. An apparatus according to claim 11 and a means to reciprocate the workpiece.

13. An apparatus according to claim 11 and a means to rotate the workpiece.

14. An apparatus according to claim 11 and a means to adjust the space between the electrode and the workpiece.

15. An apparatus according to claim 11 and a means to reciprocate and rotate the workpiece.

16. An apparatus for reducing the surface of a workpiece comprising:
   a. a means to hold a workpiece;
   b. a pair of electrodes disposed in close proximity to the surface of the workpiece;
   c. an abrasive slurry in the space between the electrodes and the workpiece;
   d. means to generate successive electric arcs between the electrodes, in the slurry, adjacent to the workpiece.

   * * * * *