Oct. 20, 1970 W. KULISCHENKO 3,534,503

ABRADING APPARATUS

Filed Aug. 21, 1967 2 Sheets-Sheet 1

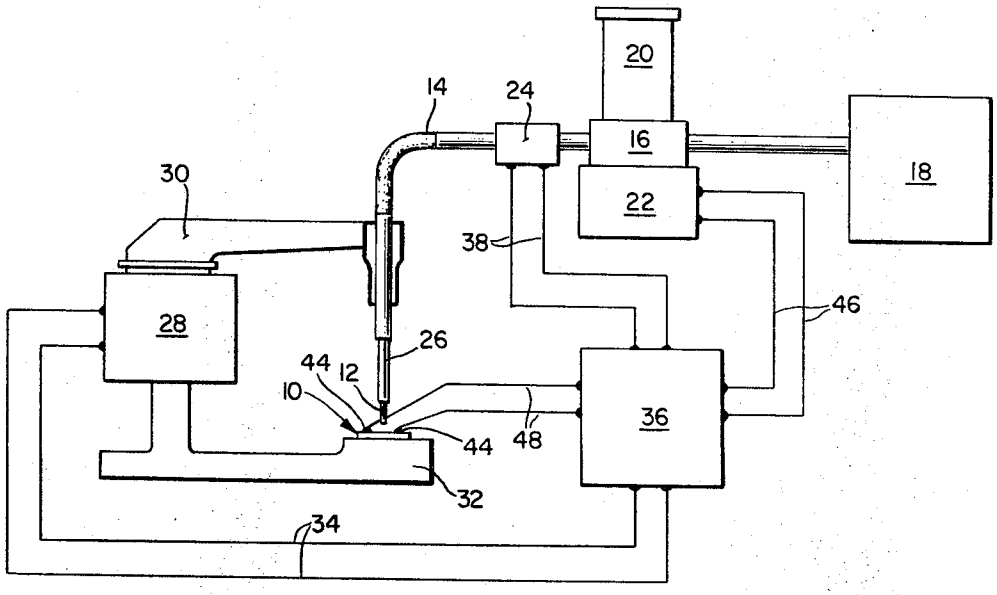


Fig. 1

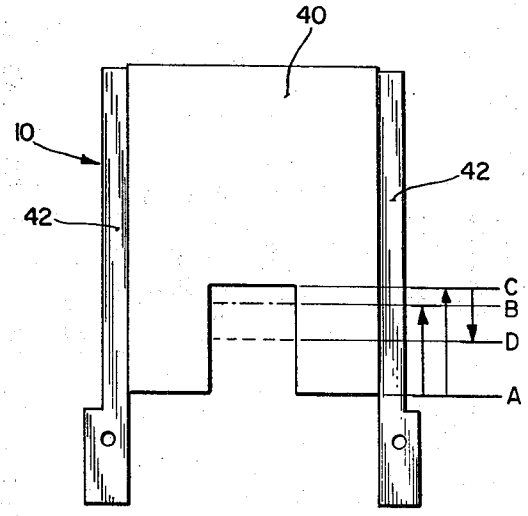


Fig. 2

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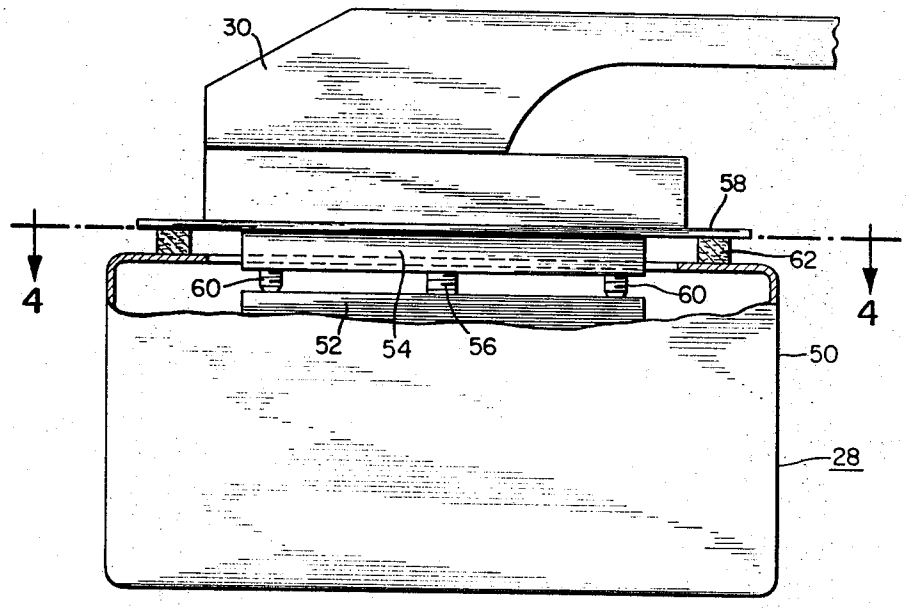


Fig. 3

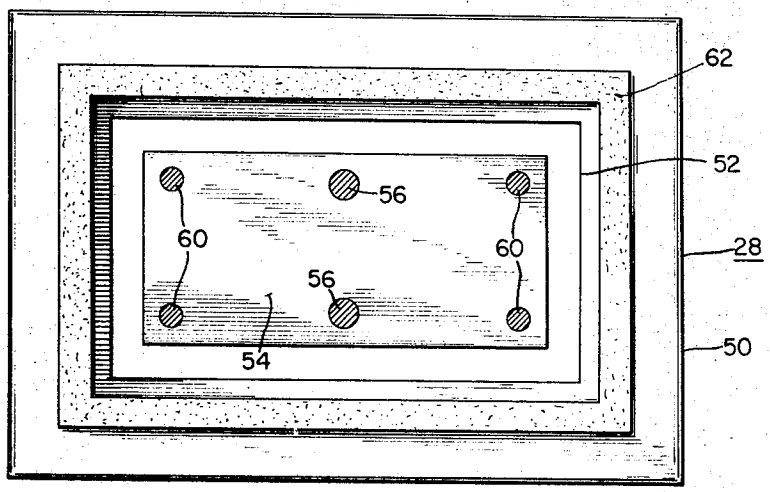


Fig. 4

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ABRADING APPARATUS

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Int. Cl. B24c 3/04
U.S. Cl. 51—8 4 Claims

ABSTRACT OF THE DISCLOSURE

Miniature electrical resistors having a resistive film on a non-conductive substrate are abrasively trimmed to increase their resistance to a desired value by moving an abrasive jet between the resistor terminals, while measuring the rate of resistance increase, and then stopping and reversing the movement of the jet at a projected point in time when resistance has increased to the desired value. Capacitors and other electrical elements can be trimmed by this method. The apparatus has means for traversing the nozzle which issues the abrasive stream, also a control which responds to measurements of the extent of abrasion of the resistor or workpiece for stopping and reversing the direction of movement of the nozzle; and optionally the control interrupts the flow of abrasive material. In its preferred form the traversing mechanism has an opening sealed by a movable platform which transmits motion to the nozzle.

This invention relates to apparatus for carefully removing material from a workpiece such as a miniature electrical resistor.

Miniature electrical resistors comprise a conductive film of electrically resistant material on a non-conductive substrate between spaced terminals. Such miniature resistors are made by first printing a slightly excessive amount of film on the substrate and then removing a portion of the film between the terminals so as to reduce the cross-sectional area disposed between the terminals until the electrical resistance of the element is adjusted upwardly to the desired value. Although various methods have been employed heretofore for removing material coated on a substrate, the present invention is directed to a method and an apparatus for removing material by abrasion.

The basic abrading apparatus comprises an air supply, a powder reservoir with vibrator and mixing chamber, and a supply conduit fitted with an appropriate nozzle. Under pulsation from the vibrator abrasive powder trickles into the pressurized air stream, the amount depending on the amplitude of vibration. A rheostat may be employed to regulate the amplitude of vibration and, consequently, the intensity of abrasive cutting action.

To the basic abrading apparatus is added an electronic control and measuring system, also a controlled drive with fast stop-action for the nozzles. It is contemplated that a workpiece such as a resistor will be placed in a holder. Thereafter, on signal the machine automatically lowers probes over resistors to be trimmed, measures them, starts the abrasive jet flow and nozzle motion, continues to monitor resistance, and stops the entire proceedings when predetermined resistance values have been reached.

The present invention therefore involves measuring the rate at which the electrical resistance of the resistor is increased with respect to the speed of movement of the jet, then projecting the additional time required to further increase the resistance to the desired value, and stopping and reversing the movement of the jet at the point in time thus determined. With proper compensation

for overshoot, the milliseconds of time elapsed between initiating and effecting stopping of travel of the jet, together with a highly responsive braking and reversal mechanism, trimming can be accomplished with a high degree of accuracy.

Provision is made to protect the traversing mechanism from damage by spent abrasive particles by interposing a seal between a margin surrounding an opening in its housing and the appended parts which transmit motion to the nozzle, all of which is described hereinafter in greater detail.

In the drawings:

FIG. 1 is a schematic illustration of apparatus constructed and arranged for carrying out the invention;

FIG. 2 is a plan view of a miniature electrical resistor, shown greatly enlarged, of the type which can be trimmed abrasively according to the present invention;

FIG. 3 is a fragmentary elevational view of the apparatus, with portions broken away, illustrating the traversing mechanism in detail; and

FIG. 4 is a horizontal sectional view through the apparatus, taken along lines 4—4 of FIG. 3.

The illustrated abrading apparatus will now be described as applied to the trimming of a thick-film resistor or other workpiece designated generally by the numeral **10**, utilizing a high velocity abrasive stream issuing from a nozzle **12**. The latter is supplied through a supply conduit **14** by a mixing chamber **16** where dry, filtered, pressurized air at about 85 p.s.i. from a compressor **18** is uniformly mixed in the desired proportions with abrasive powder from a reservoir **20**. By means of a unique arrangement more fully described in the present inventor's application Ser. No. 365,123, filed May 5, 1964, now U.S. Pat. No. 3,344,524, a vibrator **22** is employed to apply vibrations to the chamber **16**. This arrangement can produce an automatically replenished trickle of about 3 to 5 grams per minute of aluminum oxide or other abrasive powder having an average particle size of 27 microns, from the reservoir **20** through a passageway (not shown) to the mixing chamber **16** for combining with the pressurized air.

The flow of airborne abrasive particles is initiated by the energization of a solenoid operated pinch valve **24** in the upstream end of the supply conduit **14**, that is, at the outlet of the mixing chamber **16**. The nozzle **12** will have a restricted orifice, e.g. .018 inch diameter, of much smaller cross-sectional flow area than the supply conduit **14**, and thus the entire system is pressurized. In order to achieve uniform cutting action the apparatus is arranged to provide a uniform concentration of particles in a constant airstream issuing from the nozzle at about 40 to 80 p.s.i.

The supply conduit **14** may be a flexible hose of abrasion resistant material at the end of a length of rigid tubing, and it is preferred that the terminal or end portion adjacent the nozzle **12** be of rigid tubular construction so that it can serve as nozzle holder **26** capable of having its movements accurately controlled by a traversing mechanism **28** connected thereto by a rigidly constructed arm **30**. The nozzle holder **26** is suitably journalled in the extended free end of the arm **30**, in upright position above a holder **32** for the workpiece **10**. Further details of construction of the traversing mechanism **28** appear herein and it is noted here that the mechanism **28** serves to move the nozzle **12** by its holder **26** transverse to the longitudinal extent of the holder, or into and out of the plane of the drawing illustrating the apparatus, whereby the abrasive stream is traversed along the length of the workpiece to cut or abrade along the line of travel. The traversing mechanism **28** responds to signals received via conductors **34** from a control **36** to

move a controlled distance first in one direction and then usually in opposite or reverse direction upon completion of an abrading operation. The control **36** also sends energizing current through conductors **38** to the solenoid of pinch valve **24** to effect its closing upon completion of an abrading operation; but otherwise during abrasive trimming the pinch valve **24** is held open.

The workpiece **10** shown in FIG. 2 is an electrical resistor having a thick, electrically resistive film **40** printed on a correspondingly shaped substrate and having a pair of terminals **42** joined to opposed parallel edges thereof. As shown, the resistor **10** has been trimmed between the lines designated by the letters A and C. Phantom line B indicates the point at which a stop and reverse signal was issued from the control **36**; and the trimmed area lying between lines B and C represents the amount of film **40** trimmed by over-shooting during the 5 milliseconds of elapsed time between issuance of the signal and the actual point of stopping. Broken line D represents the point at which abrasive flow ceased during reverse movement of the nozzle, approximately 20 milliseconds following issuance of the stop signal at B. It can be seen that abrasive material continues to flow as the nozzle travels from B to C and then in reverse direction from C to D. Obviously no material is removed from the film **40** during reverse movement of the nozzle between C and D because the material was already removed during forward motion between A and C. The present invention recognizes that control **36** must anticipate the removal of material from film **40** while overshooting between B and C.

Referring again to FIG. 1, a pair of probes **44** are connected during trimming between terminals **42** and control **36** by conductors **48** so that the electrical resistance of the resistor **10** can be continuously monitored by the control **36** as work proceeds.

The vibrator **22** may be connected as shown to the control **36** by conductors **46**. The concentration of abrasive particles in the abrasive jet can be set by adjusting the amplitude of vibrations applied to the mixing chamber in direct relation to the desired abrasive capability of the jet since the cutting action of the abrasive stream corresponds to the abrasive concentration.

The traversing mechanism **28** of FIGS. 3 and 4 includes a housing **50** enclosing a motor (not shown) in driving relationship with a motion translating mechanism **52**. The latter translates rotary motion of the motor into horizontal linear motion in the illustrated arrangement. Such motion is transmitted from the mechanism **52** through a plate **54** (connected thereto by bolts **56**), a generally flat platform **58**, and an arm **30** to the nozzle holder **26**. The plate **54** is disposed in an opening in the generally flat top wall of the housing **50**, with the marginal portions of the housing about the opening spaced from the plate **54** to limit the horizontal motion thereof within the confines of the opening and to correspondingly limit the linear motion of the mechanism **52**.

Between the plate **54** and the motion transmitting mechanism **52**, a set screw **60** is interposed at each of the four corners thereof. The set screws **60** serve to adjust the spacing between the top surface of the housing **50** and the bottom surface of the platform **58**, and also to adjust the compression of a seal member **62** disposed therebetween. The seal **62** is preferably made of felt or other soft and fine solids impervious material, and it is secured by an adhesive cement to the top wall of the housing **50** so as to extend entirely around the opening therein. With the margin of the platform **58** slidably resting on the seal member **62**, access to the interior of the housing **50** through the top opening is closed. And by adjustment of the set screws **60** the compressive force on the seal **62** can be set to maintain a good seal and yet permit free sliding motion of the platform **58**. To assist in free sliding motion of the platform **58** on the seal **62** the lower surface of the platform **58** is provided with a low friction coating such as Teflon.

According to the operation of the apparatus of the present invention, the electrical resistor **10** is trimmed by directing a jet of airborne abrasive particles toward the film **40** at close range, while moving the jet at constant forward speed across part of the surface of the film in a path between the terminals **42** so as to reduce its cross-sectional area. While moving the jet the increasing resistance of the resistor **10** is continuously measured and the additional time required to further increase resistance to the desired value can be projected. After offsetting the time involved in removing additional material during overshooting, as described with reference to FIG. 2, the precise point in time for initiating stopping and reversing can be determined. As a result, reversal of the moving jet is effected after compensation for overshooting so that the film material remaining has the desired electrical resistance within a high degree of accuracy. With forward nozzle travel speeds of one inch per minute, resistor values within plus or minus one-tenth percent can be achieved without difficulty; with trimming speeds up to 6 inches per minute, accuracy within $\frac{3}{10}$ percent can be obtained; and where less accuracy is required, trimming speeds can be increased to and beyond 15 inches per minute.

When performing highly accurate trimming tasks at the slower speeds, it is nevertheless desirable and permissible to effect reverse movement of the nozzle at maximum speed. For example, during trimming on forward motion it may be that one inch per minute of travel speed is desirable to obtain the desired accuracy, and reverse movement can be accomplished at a maximum travel speed of say 15 inches per minute so as to minimize the total time of each trimming cycle.

For maximum accuracy, trimming should be accomplished by moving the nozzle, not only at constant forward speed, but also with a constant distance between the nozzle **12** and the film **40**.

The control **36** may incorporate a 4-wire resistance limit bridge, integral to the electrical control system, for monitoring the resistor as it is being trimmed and sending a signal to the pinch valve **24** and to the traversing mechanism **28** in the manner and at the time described.

Although the invention has been described as applied to the trimming of electrical resistors, the invention is also applicable to the trimming of other kinds of electrical elements such as capacitors. Miniature capacitors are well known to be made of a dielectric material between two conductive members to which terminals are connected. In such case the capacitance of the capacitor is measured as trimming of a metal conductive member (and/or dielectric material) takes place to monitor the changing electrical value as trimming progresses. It follows, therefore, that as expressed in the claims, the term "electrical value" or "value" is applicable to measurement of resistance (ohms), as well as capacitance (farads, microfarads, or micromicrofarads) or any other kind of unit of electrical value susceptible of measurement. And the method and apparatus are applicable to workpieces other than components of electrical circuitry, particularly when measurement of an electrical value thereof is indicative of the amount of material present, and thus indicative also of the extent of abrasion accomplished by the method and apparatus. Likewise, the method and apparatus can be employed whether trimming effects an increase or decrease in the electrical value being measured. Trimming of a capacitor, for example, may produce a decrease in capacitance; and this measurement may be employed to effectively control trimming downwardly to the desired capacitance in the same manner as upward adjustments of resistance of a resistor. In some instances the measurement may be of impedance or inductance, depending of course on the value or characteristic of interest.

What is claimed is:

1. In abrading apparatus for removing material from a workpiece by directing a high velocity stream of abrasive particles through a nozzle to said workpiece, and wherein

said abrading apparatus includes means for traversing said nozzle relative to said workpiece, and said traversing means contains a motion translating mechanism for effecting movement of said nozzle, that improvement wherein the traversing means comprises a housing containing said motion translating mechanism including a substantially flat wall portion provided with an opening and a compressible seal member on said wall portion surrounding said opening, a platform connected through said opening to said mechanism and having marginal portions thereof slidably resting on said seal member to close access to the interior of said housing through said opening, and structure connected between said platform and said nozzle for transmitting the motion of said mechanism to said nozzle.

2. Abrading apparatus according to claim 1 including means for adjustably connecting said platform and said mechanism for varying the compressive force of said seal member between said platform and the wall portion of said housing.

3. Abrading apparatus according to claim 2 wherein the edges of the wall portion about said opening are closely spaced from the means connecting said platform and said mechanism to limit the motion thereof within the confines of said opening and to correspondingly limit the motion of said mechanism.

4. Abrading apparatus according to claim 2 wherein the surface of said platform contacting said seal member is provided with a low friction coating.

References Cited

UNITED STATES PATENTS

2,773,332 12/1956 Buchman et al. ..... 51—15

FOREIGN PATENTS

390,476 6/1931 Great Britain.

LESTER M. SWINGLE, Primary Examiner