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[54] **METHOD AND MEANS OF GRINDING WITH ELECTROPHORETIC ASSISTANCE**

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[52] **U.S. Cl.** **51/322**

[51] **Int. Cl.** **B24b 1/00**

[58] **Field of Search** ..... 51/84 R, 281 R, 316, 322, 51/323, 267

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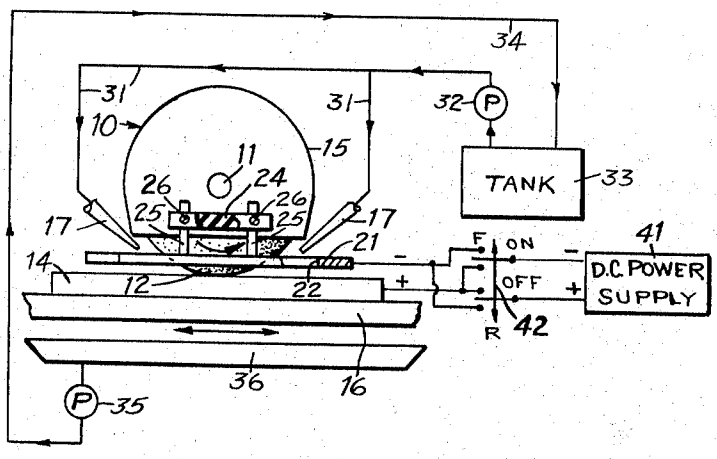
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[57] **ABSTRACT**

A grinding system in which an electrically conductive workpiece is moved against and relative to a rotating grinding wheel, an electrode spaced from and electrically insulated from the workpiece, means to maintain the space between the workpiece and the electrode filled with an electrically substantially nonconducting coolant fluid containing electrically charged particles of a cutting fluid or other cutting agent, and a direct current power source connected to so charge the workpiece and the electrode that the charged particles of a cutting fluid or other cutting agent migrate to and form a film upon the surface of the workpiece as it passes beneath the grinding wheel.

9 Claims, 5 Drawing Figures



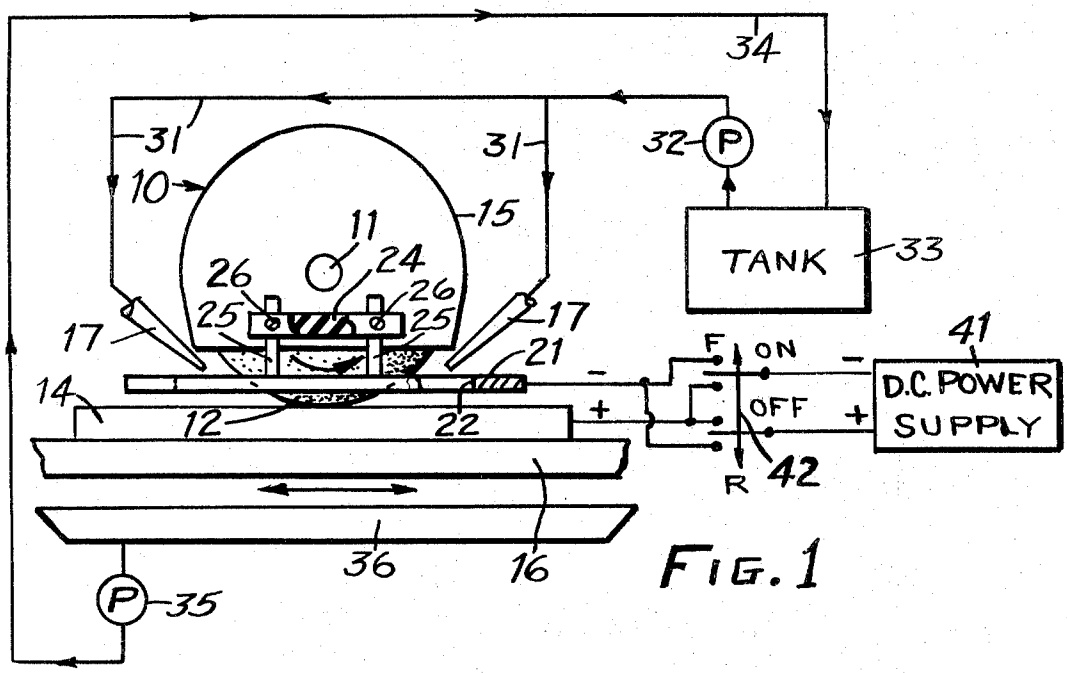


FIG. 1

FIG. 2

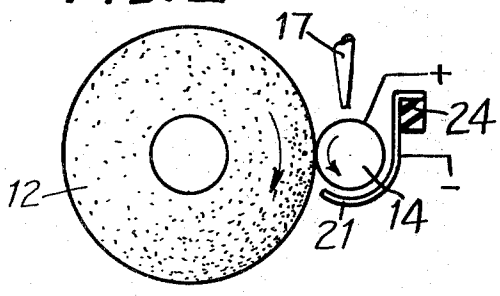
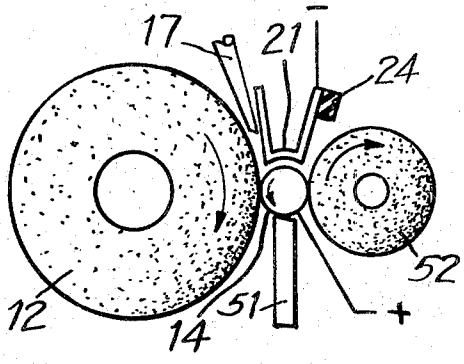


FIG. 3



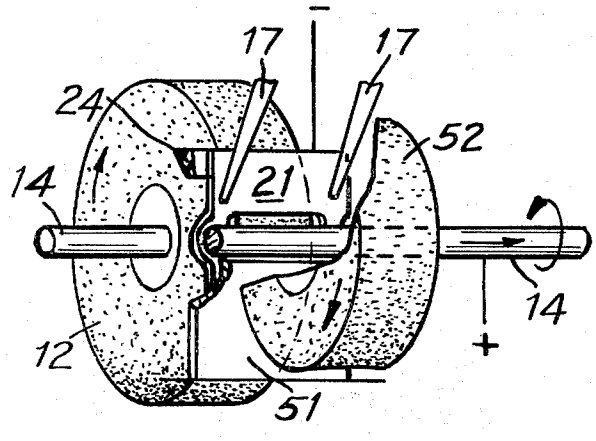


FIG. 4

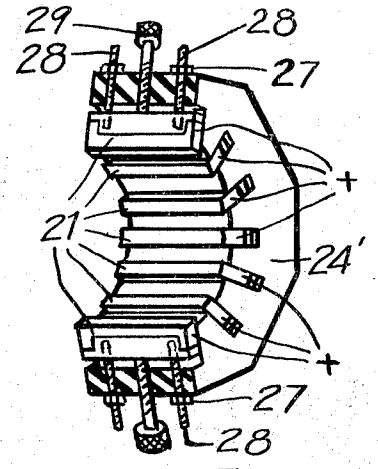


FIG. 5

METHOD AND MEANS OF GRINDING WITH ELECTROPHORETIC ASSISTANCE

BACKGROUND OF THE INVENTION

1. Field of Invention

This invention relates to an arrangement for wet grinding a workpiece, and more particularly to a grinding arrangement in which an electrically conducting workpiece moved against and relative to a suitable grinding element such as a grinding wheel, for example, is flooded adjacent the grinding site with a nonconducting fluid stream containing charged particles of a grinding or cutting agent and subjected to a voltage gradient such that the particles of a grinding or cutting agent entrained in the fluid are attracted to and form a film upon the surface of the workpiece adjacent to the grinding site.

2. Description of the Prior Art

It is well known in the grinding art that the heat generated at a grinding site during a sustained grinding operation may cause the temperature at that site to reach levels detrimental to the workpiece or the grinding wheel, or both. This temperature rise to a harmful level may be postponed at least for a relatively extended period of time or indefinitely by supplying to the grinding site a substantial quantity of a suitable coolant fluid, for example, water.

Alternatively, it is also well known in the grinding art that the efficiency with which a grinding wheel performs can be considerably improved by supplying to the grinding site a quantity of a grinding or cutting fluid such as a suitable oil. However, since such oils lack the cooling properties of a coolant fluid such as water, this increased efficiency is accompanied by a rapid rise in temperature to a harmful level.

In order to combine the benefits of these fluids differently affecting grinding operations, it is widespread practice for many different grinding operations to supply to the grinding site a mixture of a coolant fluid and a grinding or a cutting fluid, for example, one part of a suitable oil to from 20 to 40 parts of water. Thus, some improvement in the efficiency of the grinding operation due to the presence of the cutting fluid is achieved under favorable relatively low temperature conditions maintained by the coolant fluid.

A further improvement in efficiency, still accompanied by favorable relatively low temperature conditions, has been achieved by delivering the combination of oil and water separately to the grinding site, for example, one part of oil delivered at high velocity through very small nozzles to the surface of the grinding wheel adjacent to the grinding line, and 40 parts of water delivered at very low velocity through a large nozzle to the surface of the workpiece. For further particulars see Wagner et al U.S. Pat. No. 2,434,679 issued Jan. 20, 1948. This system necessarily poses one of two problems, either a requirement for sustained fresh supplies of oil and water, or, alternatively, a requirement for a relatively complex fluid separating means illustrated in FIG. 14 of the patent, effective to separate the oil and water for recirculation through the respective separate nozzle assemblies.

In contrast to the separate fluid delivery systems and the complementary fluid separating means required by the apparatus described above, the instant invention accomplishes substantially the same separation of coolant and cutting fluids at the grinding site relying solely on an electric field.

In order to remove stock more efficiently from materials relatively hard to grind such as hard metal alloys and carbides, various systems for electrolytically assisted grinding have been devised, typically including provisions for delivering a relatively heavy electric current across the narrow space maintained by nonconducting abrasive particles between a negatively charged electrically conducting bond portion of a grinding wheel and a positively charged electrically conducting workpiece. This substantial electric current is carried by an electrically highly conductive electrolyte such as a suitable salt solution.

In one such electrolytically assisted grinding system, the flow of a large current to the workpiece is facilitated by a conducting shoe having a relatively large surface conforming to the surface of the workpiece and insulated therefrom by nonconducting particles in a manner similar to the manner in which the workpiece is insulated from the conducting portion of the grinding wheel. The electrolyte may either be delivered to the space between the shoe and the workpiece from a source adjacent to the shoe, or be delivered to a chamber within the shoe and thence through perforations in its face adjacent to the workpiece. See Blake U.S. Pat. No. 3,285,843 issued Nov. 15, 1966.

The apparatus described above is effective to assist in the removal of stock from a positively charged workpiece, while the instant invention is effective to deposit a film of a cutting agent upon the surface to be ground of a workpiece.

In another such electrolytically assisted grinding system, the electrical circuit is operative periodically to reverse the flow of current to interrupt the deplating action on the workpiece and instead to deplate metal build up on the grinding wheel and to dress the conductive metal bond portion of the grinding wheel. See Kistler U.S. Pat. No. 2,920,026 issued Jan. 5, 1960.

The reversal of the electric current periodically in the apparatus described above is effective to produce deplating and dressing of the grinding wheel alternately with stock removal from the workpiece, while reversal of the voltage gradient in the instant invention is effective alternately to deposit a film of cutting field on the surface to be ground of a workpiece during a grinding operation, and to remove a cutting fluid from the surface of a workpiece after the grinding operation is completed.

SUMMARY OF THE INVENTION

The instant invention contemplates in a grinding machine a method and apparatus wherein an electric field established between an electrode and a workpiece to be ground is effective during a grinding operation to cause the migration of particles of a cutting agent entrained in a coolant fluid to form a film composed of the particles of a cutting fluid or other cutting agent upon the surface to be ground of a workpiece.

The instant invention also contemplates in a grinding machine a method and means of removing the film of a cutting fluid from the surface of a workpiece by reentraining the particles of a cutting fluid in the coolant fluid after a grinding operation is completed.

An object of the present invention is the provision of simple and effective means operative during a grinding operation to separate particles of a cutting fluid or

other cutting agent from a coolant fluid in which they are entrained, and to deposit upon the surface to be ground of a workpiece a film composed of the particles of a cutting fluid or other cutting agent previously entrained in the coolant fluid.

Another object is the provision of means operative after a grinding operation to reentrain in a coolant fluid a film of cutting fluid deposited upon the surface of a workpiece.

Still another object is the provision of a method for depositing upon the surface to be ground of a workpiece a film formed from particles of a cutting fluid previously entrained in a stream of coolant fluid, and for removing the film of cutting fluid after a grinding operation is completed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side elevation of a simplified schematic representation of the preferred embodiment of the instant invention applied to a surface grinding machine,

FIG. 2 is a side elevation of a simplified schematic representation of the instant invention applied to a cylindrical grinding machine,

FIG. 3 is a side elevation of a simplified schematic representation of the instant invention applied to a centerless grinding machine,

FIG. 4 is a perspective view of an alternative embodiment of the instant invention applied to a centerless grinding machine, and

FIG. 5 is a perspective view, partially in section, of a modified electrode assembly for a cylindrical grinding machine.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring first to FIG. 1 comprising a simplified schematic representation of a conventional surface grinder generally designated by the reference numeral **10**, a motor driven shaft **11** supports a grinding wheel **12** for vertical feeding movement relative to a workpiece **14** and for counterclockwise rotation as seen in FIG. **1**. The grinding wheel is enclosed by a conventional wheel guard **15** and the workpiece **14** is supported upon a workpiece supporting table **16** reciprocated and transversely fed by means not illustrated, since they are well known in the art and form no part of the instant invention. The wheel guard **15** supports two or more fluid discharge nozzles **17** and an electrode **21** shown as comprising a generally rectangular flat plate with a central opening **22** therethrough to accommodate the peripheral portion of the grinding wheel **12** positioned to engage the surface of the workpiece **14**. The electrode **21** may be supported adjacent to but spaced from the workpiece **14** by a supporting assembly on at least one side of the wheel guard **15**, including an electrically insulating block **24** secured to the wheel guard **15**, a pair of supporting rods **25** each secured at one end to the electrode **21**, and a pair of locking screws **26** each threadably engaging the insulated block **24** and operative to secure one of the supporting rods **25** against movement relative to the insulating block **24**. If used, a second electrode supporting assembly on the other side of the wheel guard **15**, not shown in FIG. **1**, preferably is generally similar if not identical to the first electrode supporting assembly illustrated in FIG. **1**.

The coolant fluid of the instant invention and the particles of a cutting fluid or other cutting agent entrained therein are supplied to the space between the workpiece **14** and the electrode **21** by two or more nozzle assemblies **17** connected through conduits **31** and pump assembly **32** to a tank **33**, also connected through return conduit **34** and pump **35** to an open tray **36** located beneath the reciprocating table **16** to collect and return the combined fluid to the tank **33** for recirculation.

The direct current power supply **41** is connected through switch assembly **42** to the workpiece **14** and the electrode **21** so that the workpiece is charged positively and the electrode is charged negatively when the switch assembly **42** is in its on position. The switch assembly **42** is selectively movable to an off position in which the workpiece and the electrode are disconnected from the power supply and to a reverse position in which the workpiece **14** is connected to the negative side of the power supply and the electrode **21** is connected to the positive side of the power supply.

During a grinding operation, the pump **32** is operated at a rate sufficient to deliver from nozzles **17** a stream of coolant fluid and entrained negatively charged particles of a cutting fluid or other cutting agent, for example, droplets of an emulsified oil sufficient to substantially fill the space between the surface to be ground of the workpiece **14** and the electrode **21**. With the switch assembly concurrently positioned in its on position there is created an electromotive force between the workpiece **14** and the electrode **21** effective to cause the negatively charged droplets of an emulsified oil, to migrate to the surface to be ground of a positively charged workpiece **14**, where these droplets collect to form a thin film, not shown in FIG. **1**, which passes between the surface of the workpiece **14** and the grinding wheel **12** as the workpiece is reciprocated beneath the grinding wheel. Such migration of the charged particles is characteristic of the process known as electrophoresis.

When the grinding operation is completed, the switch assembly **42** may be moved to its open position to deenergize the workpiece **14** and the electrode **21**, thereby allowing the stream of coolant fluid passing over the workpiece **14** to reentrain and remove the droplets of oil which have formed the film on the surface of the workpiece during a grinding operation. Alternatively, when the grinding operation is over, the switch assembly **42** may be moved to its reverse position so that the workpiece **14** is negatively charged and the electrode **21** is positively charged, thus encouraging the movement of the oil droplets away from the surface of the workpiece with the stream of coolant fluid.

The improvement in the effectiveness of a grinding operation due to electrophoretic assistance, that is by the application of electrophesis, is indicated in the following table by the increase in the grinding ratio for electrophoretic grinding performed with the grinding wheels specified at various different voltage levels, as compared to the grinding ratio achieved by conventional grinding operations performed with the same grinding wheels on the same material under otherwise corresponding operating conditions. The grinding ratio as used here is the ratio of the pounds per hour of metal removed to the cubic inches per hour of grinding wheel wear during a grinding operation.

TABLE I

Hard Huron Die Steel

Process Used / Wheel Specification	Grinding Ratio, G, With Applied Voltage of			
	0	0	0	0
Conventional (32A461-J8VBE)	5.26	5.18	4.96	4.99
	5.05	5.24	5.21	4.95
Average	5.16	5.21	5.09	4.97
	15	32	60	80
Electrophoretic (32A461-J8VBE)	6.44	6.27	6.29	6.42
	5.45	6.80	6.19	5.79
Average	5.95	6.54	6.24	6.11
	(+15%)	(+26%)	(+23%)	(+23%)

Process Used / Wheel Specification	Grinding Ratio, G, With Applied Voltage of	
	0	
Conventional (32A461-L8VBE)	7.66	
	8.12	
Average	7.89	
	32	
Electrophoretic (32A461-L8VBE)	9.28	
	9.10	
Average	9.19	
	(+18%)	

No. 302 Stainless Steel

Process Used / Wheel Specification	Grinding Ratio, G, With Applied Voltage of	
	0	0
Conventional (32A461-J8VBE)	7.03	10.28
	7.69	9.03
Average	7.36	9.65
	32	80
Electrophoretic (32A461-J8VBE)	13.06	16.33
	11.03	15.86
Average	12.04	16.10
	(+62%)	(+67%)
	0	0
Conventional (32A461-L8VBE)	11.35	8.47
	11.06	7.72
Average	11.20	8.10
	32	80
Electrophoretic (32A461-L8VBE)	15.44	15.49
	15.05	11.27
Average	15.25	13.38
	(+36%)	(+65%)

Conditions for the comparative grinding tests summarized in Table 1 above were as follows:

Machine Used—Norton S-3 Surface Grinder

Material Used—Hurton die steel, RHC59, 1.995 × 8.075" C.S.; No. 302 Stainless Steel—1.967 × 8.040" C.S.

Wheel Speed (Initial)—6000 s.f.p.m. (approx.)

R.P.M.—2840-50

Down-feed—0.001 or 0.002"/complete cross-fed

Cross-feed—0.050"/pass

Total down-feed—0.020"/run

Coolant—WHEELMATE No. 803*, 1/20 parts water

Dressing—Diamond, initially only

Traverse—600"/min.

*WHEELMATE No. 803—A sulfo-chlorinated soluble oil which mixes readily with water to form a stable emulsion.

From consideration of the respective grinding ratios achieved while grinding Hard Huron Die Steel, it will be evident the grinding ratio is improved in this instance by from 15 to 26 percent when electrophoretic grinding is used. Similarly, from consideration of the grinding ratios achieved while grinding relatively harder No. 302 Stainless Steel it will be apparent that the grinding ratio is increased by from 35 to 67 percent when electrophoretic grinding is used. Thus, the results disclosed in Table I above indicate that the beneficial effect of electrophoretic grinding increases in direct proportion to the relative hardness and consequently the relative difficulty encountered in grinding various different materials by conventional grinding means.

Referring now to FIG. **2**, the instant invention is shown applied to a simplified schematic representation of a cylindrical grinding machine including a grinding wheel **12** supported on and rotated clockwise by a drive shaft driven by a wheel drive motor not shown, a workpiece **14** rotated counterclockwise at a relatively much lower rate by a work drive motor not shown, at least one nozzle **17** for delivering a stream of coolant fluid with entrained particles of a cutting fluid, and electrode **21** having a portion thereof conforming to but spaced a uniform short distance from the surface of the workpiece **14**, and an electrically insulated block **24** supporting the electrode **21**. In this configuration as in that illustrated in FIG. **1**, the workpiece **14** may be connected to the positive terminal and the electrode **21** may be connected to the negative terminal of a direct current power supply, so that negatively charged particles of a cutting fluid, such as an emulsified oil, migrate through the coolant fluid to the surface of the positively charged workpiece **14** to form a film which passes between the grinding wheel **12** and the workpiece **14** as the workpiece is ground.

Referring next to FIG. **3**, the instant invention is shown applied to a simplified schematic representation of a centerless grinding machine including a grinding wheel **12** supported on and rotated clockwise by a drive shaft driven by a wheel drive motor not shown, a workpiece **14** rotated counterclockwise on a work rest blade **51** at a relatively lower rate by a regulating wheel **52** rotated clockwise by a wheel drive motor not shown, at least one nozzle **17** for delivering a stream of coolant fluid with entrained particles of a cutting fluid, electrode **21** having a portion thereof conforming to but spaced a uniform short distance from the surface of the workpiece **14**, and an electrically insulated block **24** supporting the electrode **21**.

In this configuration as in those illustrated in FIGS. **1** and **2**, the workpiece **14** may be connected to the positive terminal and the electrode **21** may be con-

nected to the negative terminal of a direct current power supply, so that negatively charge particles of a cutting fluid, such as an emulsified oil, migrates through the coolant fluid to the surface of the positively charged workpiece **14** to form a film which passes between the grinding wheel **12** and the workpiece **14** as the workpiece is ground.

Referring here to FIG. **4**, an alternative embodiment of the instant invention is shown applied to a simplified schematic representation of a centerless grinding machine including a grinding wheel **12** supported on and rotated clockwise by a drive shaft driven by a wheel drive motor not shown, an elongated workpiece **14** supported upon a work rest blade **51** and rotated counterclockwise at a relatively lower rate by a regulating wheel rotated clockwise by a drive motor not shown, at least two nozzles **17** for delivering streams of coolant fluid with entrained particles of a cutting fluid, electrode **21** having a portion thereof conforming to but spaced a uniform short distance from the surface of the workpiece **14**, and an electrically insulated block **24** supporting the electrode **21**.

In this configuration as in those illustrated in FIGS. **1**, **2** and **3** the workpiece **14** may be connected to the positive terminal and the electrode **21** may be connected to the negative terminal of a direct current power supply, so that negatively charged particles of a cutting fluid, such as emulsified oil, migrate through the coolant fluid to the surface of the positive charged workpiece **14** to form a film which passes between the grinding wheel **12** and the workpiece **14** as the workpiece is ground. In addition, because of the relative dispositions sequentially of the electrode **21**, the work rest blade **51**, and the line of contact between the grinding wheel **12** and the workpiece **14**, the film of cutting fluid deposited upon the surface of the workpiece passes across and thereby lubricates the working edge of the work rest blade to reduce or eliminate blade wear.

It will be obvious the film of a cutting agent deposited upon a surface to be ground of a workpiece, which actually passes beneath the grinding wheel, will be ground away. However, in many grinding machine, workpiece, electrode configurations, the film will be redeposited on portions of the workpiece surface already ground. For example, see one such configuration in FIG. **1**.

Accordingly, the operation of the apparatus illustrated in FIG. **1**, as described, includes interruption or reversal of the connections to the power supply **41**, by operation of switch assembly **42** after the grinding operation is completed to provide for at least partial removal of the residual film on the ground workpiece.

The same capability for at least partial removal of residual film may be provided, as necessary, in any of the configurations illustrated in FIGS. **2**, **3** and **4** by connecting the workpiece **14** and the electrode **21** to the power supply **41** through a switch assembly **42** as shown in FIG. **1**.

In a grinding machine configuration in which a ground workpiece is moved rapidly away from the grinding wheel, as in FIG. **4**, the electrode **21** may be substantially elongated to extend the length of the discharged workpiece, that is to the right in FIG. **4**, for example, and additional nozzles **17** may be used to distribute the fluid stream along the length of the discharged workpiece, so that reversal of the electrical connections to the workpiece and the electrode after the workpiece has passed over the work rest blade **51** shown in FIG. **4** will be effective to remove at least a portion of the residual film from the discharged workpiece.

The electrical connections shown schematically in FIG. **1** as connected directly to the workpiece **14** and the electrode **21** may alternatively be connected indirectly thereto through electrically conducting elements associated therewith, for example, through the table **16** supporting the workpiece **14** or through a rod **25** connected to the electrode **21**.

The specific means of coupling the electrical connection to the workpiece **14** in each of the grinding machine configurations shown in FIGS. **2**, **3** and **4** is not shown, because the details of such connections form no part of the instant invention. However, it will be apparent such connection may be made through any type of electrically conducting supporting means for the workpiece such as an assembly including a workpiece center or a face plate with clamping jaws.

Alternatively, the coupling may be made directly to a rotating workpiece through a brush or shoe assembly maintained in electrically conducting sliding engagement with the surface of the workpiece. In fact, in order to maintain the workpiece energized throughout the desired operating cycle, a rotating workpiece may be engaged continuously during the operating cycle by at least one of two or more brush or shoe assemblies respectively located on opposite sides of the grinding wheel **12**. Such an arrangement of multiple brush or shoe assemblies would be particularly useful on the grinding machine configuration shown in FIG. **4**.

Both in the various configurations illustrated herein and in other applications of the instant invention the single electrode **21** illustrated in each of FIGS. **1** through **4** may be replaced by two or more electrodes cooperating with the workpiece **14**. For example, the single electrode used on a cylindrical grinder, as shown in FIG. **2**, may be replaced with an assembly comprising an electrically insulated arcuately curved supporting segment **24'** with spaced radial slots therein, each receiving an arcuately curved electrode **21** substantially conforming to a portion of the surface of the coacting workpiece and positioned radially by an adjustable positioning screw **29** and secured by a pair of lock nuts **27** engaging a pair of supporting screws **28** fixedly attached to an insulating insert in the back of the electrode **21**. See FIG. **5** for such a unit with electrodes adjustable radially for grinding a range of workpiece diameters.

As indicated in FIGS. **1** through **4**, the configuration of the electrode **21** may be varied as necessary to adapt it to various different grinding machine and workpiece configurations, bearing in mind the importance of a favorable voltage gradient in the application of this invention, in contrast to the requirement in electrolytic grinding apparatus for a relatively high current density.

Since a given voltage potential across the power source produces a voltage gradient between the workpiece and the electrode which increases as the distance between the workpiece and the electrode is reduced, it is most efficient to reduce the spacing between the workpiece and the electrode to its practical minimum, allowing for the circulation therebetween of an adequate supply of a coolant fluid with entrained particles of a cutting agent. For example, the configuration of the instant invention illustrated in FIG. **1** has per-

formed satisfactorily with the electrode **21** spaced 1/16 of an inch from the surface of the workpiece **14.**

The nozzles **17** employed to flood the grinding site with coolant fluid may be replaced by a suitable receptacle or housing enclosing the electrode or electrodes and at least the coacting portion of the workpiece, through which the coolant fluid may be circulated by suitable inlet and outlet conduits at a rate sufficient to accommodate an adequate migration of entrained particles of a cutting agent to the surface of the workpiece.

As material is removed from a workpiece, widening the space between the workpiece and the electrode, the supporting means for the electrode may be adjusted to shift the electrode toward the workpiece to again reduce the space between the workpiece and the electrode, and thereby maintain a favorable voltage gradient.

This adjustment of the electrode supporting means may be accomplished manually, for example, by loosening the locking screws **26** shown in FIG. **1** to permit suitable movement of the rods **25** relative to the supporting block **24,** or by loosening the locking nuts **27** on the pair of supporting screws **28** and by adjusting the positioning screw **29** for each electrode **21** shown in FIG. **5.**

Alternatively, the electrode **21** may be supported on a steadyrest assembly or other supporting means therefore incorporating means automatically operable to displace the electrode supporting means accordingly as the workpiece is reduced in size during the grinding operation. For example, after a heavy roughing cut on a rough forging, the electrode supporting means could be advanced automatically to move the electrode toward the rough ground workpiece preliminary to a finish grinding pass.

Similarly, while the switch assembly **42** as shown in FIG. **1** is manually operated, it will be apparent this switch assembly can be controlled by a suitable solenoid mechanism or other automatically operable control means actuated in coordinated relation to the completion of the grinding cycle performed by the grinding machine, so that the connections to the power supply **41** are either interrupted or reversed automatically after the grinding operation is completed.

Recalling the several references above to a cutting fluid or other cutting agent, and more specifically to droplets of an emulsified oil, there are various compositions of oil used as cutting fluids, commercially available from various sources, which can be employed according to the teachings of the instant invention to provide electrophoretic assistance for a grinding operation. For example, WHEELMATE No. 803 available commercially from Norton Company is a sulfochlorinated soluble oil which mixes readily with water to form a stable emulsion. This fluid was used successfully to obtain the test results described in Table I above.

Alternatively, the cutting agent entrained in the coolant fluid for use according to the teachings of the instant invention may consist of dry particles of a suitable lubricant material such as a flourinated hydrocarbon, for example, tetrafluoroethylene. Such particles, which may be either positively or negatively charged, are usually positively charged. When such particles, positively charged, are substituted for droplets of an emulsified oil, usually negatively charged, the workpiece must be connected to the negative side and the electrode must be connected to the positive side of a source of direct current in order to produce a film of such particles on the workpiece during a grinding operation.

Since particles of a fluorinated hydrocarbon are not detached from the surface of a workpiece by interrupting the circuit to the power supply or by reversing the charges on the workpiece and the electrode, the film formed from such particles may be stripped from the surface of the workpiece after a grinding operation is completed.

While the enclosed drawings show and the accompanying description refers to a grinding wheel, a grinding system including the instant invention may employ other types of grinding elements, for example, an abrasive belt or an abrasive disc.

The above description is to be considered as illustrative only rather than as limiting in any sense, and various modifications of grinding systems incorporating the instant invention are contemplated within the scope of the appended claims.

What is claimed is:

1. A grinding system comprising,
a moving grinding element for
an electrically conductive workpiece moving against and relative to the grinding element,
electrode means spaced and electrically insulated from a surface to be ground of such a workpiece,
an electrically substantially nonconducting liquid stream comprising electrically charged particles of a cutting agent entrained in a coolanc fluid,
means arranged to deliver said liquid stream to the space between the electrode means and such a workpiece, and
a source of direct electrical current operatively connected to maintain the electrode means and such a workpiece oppositely charged, the electrically charged particles of a cutting agent being attracted to such a workpiece, whereby a film of the cutting agent is deposited by electrophoresis upon a surface to be ground of such a workpiece.

2. A grinding system as described in claim **1,**
wherein said particles of a cutting agent are negatively charged droplets of oil emulsified in the cooling fluid, and
wherein said source of direct electrical current is operatively connected to maintain the electrode means negative and to maintain such a workpiece positive.

3. A grinding system as described in claim **2** and, in addition,
means operative after a grinding operation is completed to disconnect said source of direct electrical current from such a workpiece,
whereby the liquid stream is effective to reemulsify the droplets of oil in the coolant fluid from the surface of such a workpiece.

4. A grinding system as described in claim **2** and, in addition,
means operative after a grinding operation is completed to reverse the polarity of the electrode means and of such a workpiece,
whereby the oil droplets collected on the surface of such a workpiece are rapidly returned to the liquid stream.

5. A grinding system as described in claim **1,**

wherein said particles of a cutting agent are a fluorinated hydrocarbon.

6. A grinding system as described in claim **1**, wherein said particles of a cutting agent are tetrafluoroethylene.

7. A method of grinding an electrically conductive workpiece, comprising,

moving a grinding element,

moving an electrically conductive workpiece against and relative to the grinding element,

supporting an electrode means spaced and electrically insulated from the surface to be ground of a workpiece,

delivering to the space between the electrode means and a workpiece an electrically substantially nonconducting liquid stream containing electrically charged particles of a cutting agent entrained in a cooling fluid,

connecting a source of direct electrical current so as to maintain the electrode means and a workpiece oppositely so charged that the electrically charged particles of a cutting agent are attracted to a workpiece,

whereby the grinding operation is performed under a film of the cutting agent deposited by electrophoresis upon the surface to be ground of a workpiece.

8. A method of grinding an electrically conductive workpiece as described in claim **7**, and further comprising,

disconnecting the source of direct electrical current so as to deenergize a workpiece,

whereby the particles of a cutting agent forming a film upon the surface of a workpiece are reentrained in the liquid stream.

9. A method of grinding an electrically conductive workpiece as described in claim **7**, and further comprising,

reversing the connections to a source of direct electrical current so as to reverse the charges upon the electrode means and a workpiece,

whereby the particles of a cutting agent forming a film upon the surface of a workpiece are detached therefrom and reentrained in the liquid stream.

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