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VOLTAGE GENERATOR FOR ELECTROLYTIC EROSION PROCESSES

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Fig. 1

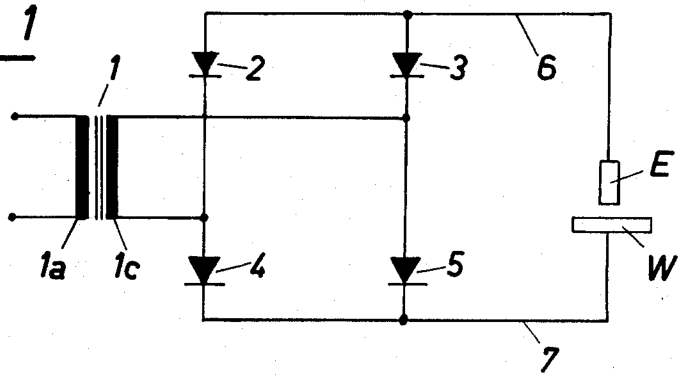


Fig. 2

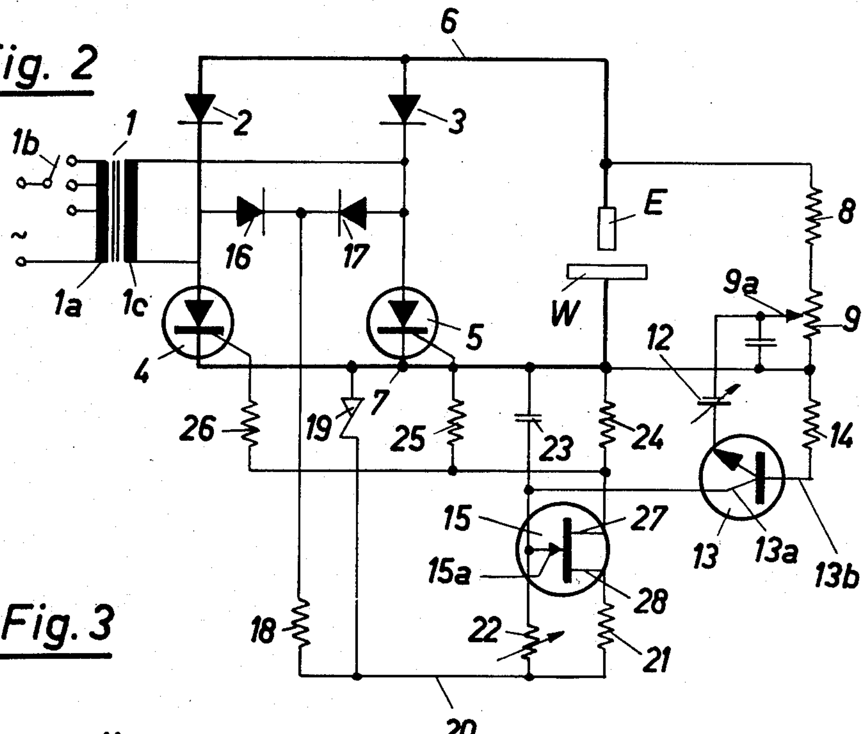
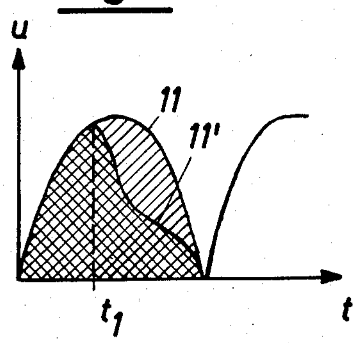


Fig. 3



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VOLTAGE GENERATOR FOR ELECTROLYTIC EROSION PROCESSES

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8 Claims. (Cl. 315—205)

The present invention relates to a novel circuit arrangement for the supply of electric energy to a machine operating on the principle of electrolytic erosion with automatic supression of arc or spark discharge across an erosion gap defined by a workpiece and tool electrode.

In the machining of hard and tough electrically conductive materials the method of electrolytic removal of material to produce geometrically simple shapes of relatively large dimensions has assumed major importance in recent years in addition to the other known processes of spark or arc-erosion material removal. In comparison with spark or arc-erosive material removal processes, the electrolytic erosion method provides the advantage that a substantially improved surface quality is obtained in addition to a greater rate of material removal, and that it provides, in comparison with the conventional classical grinding methods, absolutely flawless and smooth machined surfaces in its application in the form of the known melyzing grinding. In addition, the wear or removal of material from the electrodes is at best very small.

Physically speaking, the removal of the material is based on the electrochemical effect of a direct current passing through the surface to be machined. In melyzing grinding, for example, the grinding wheel or tool electrode, is so designed in a known manner that electrically nonconductive abrasive grains project from its surface so that a space remains between the abrasive grains and the surface to be machined in which space a suitable electrolyte is able to freely circulate. This enables a flow of current to be obtained through the electrolyte between the conductive portions of the grinding wheel and the positively poled workpiece to be machined. An anode skin produced on the surface of the workpiece is continuously removed by said abrasive grains of the tool so that said skin or coating will continuously rebuild. Apart from the removal of the anode skin carried out by means of specially designed rotating wheels, methods have been proposed wherein no rotating wheel is required. By way of example, the characteristic anode skin may be removed by vibrating electrodes or by a strong flow of the electrolytic medium to create a surface washing effect.

The removal of material and the surface quality are substantially determined in a known manner by the value of the voltage and current appearing at the machining gap, by the distance between the tool and the workpiece electrode, by the size of the surface to be machined, by the type of material and the grain size of the abrasive grains, by the composition of the base material forming the grinding wheel, by the contact pressure between the tool and the workpiece electrodes, by the peripheral velocity of the grinding wheel and by the composition and velocity of flow of the electrolyte.

A principal requirement in designing a circuit for electrolytic machining consists in avoiding spark or arc-erosion across the gap which occurs above a certain critical voltage depending on the machining problem. Such sparking or arcing causes undesirable pit formation on the workpiece surface and substantially impairs the surface quality thereof.

In known generators heretofore employed, an alternating current voltage is rectified to obtain a D.C. supply voltage for the gap. Additionally, steps must be taken

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to ensure that a largely smooth direct current voltage is supplied to the work gap. By way of example, smoothing out of the voltage may be effected by condensers, or, alternatively, a three-phase alternating-current voltage is rectified in such a manner that only slight variations of the voltage occur at the gap. However, these mentioned systems are unable to effectively avoid sparking or arcing at the gap.

According to one feature of the present invention there is provided a single phase rectifier of which the output is connected to the gap without intermediate smoothing members or filters. During each half wave cycle the voltage drops almost to zero so that at least a large portion of the arcs or sparks, if any, will automatically extinguish themselves. The energy supplied to the gap may be adjusted by regulating the ignition angle.

A circuit has been proposed and known in the art in which a high-frequency detector is incorporated in the working circuit which responds as soon as any high-frequency current changes occur. It is known that spark and arc discharges in the known specific arrangements cause rapid current changes with high-frequency characteristics so that a signal can be obtained in this manner which indicates that an undesirable spark or arc discharge has occurred in the gap. As soon as a spark or arc discharge is detected in this manner, the direct current voltage supplied is reduced until no sparks or arcs are present in the gap. To this purpose, the signal obtained is used to control the supply voltage via transductors, thyratron or plasmatron tubes. Supply is therefore effected by a circuit which comprises at least one power transformer, a control device and a work transformer. It will be appreciated that the known circuit is very costly and also subject to trouble, on the one hand, owing to the complex means required to obtain the signal and, on the other, owing to the control device.

According to the present invention the voltage generator is characterized by a rectifier arrangement supplied with alternating current voltage, a transmitting member for transmitting the pulsating direct current voltage produced by the rectifier to the erosion gap, by an integrator unit connected parallel with the erosion gap to determine the time integral of the voltage characteristic, and by means for influencing a controllable rectifier in dependence on the signal produced in the integrator unit. The invention is therefore based on the finding that the integral of an impulse decreases when an undesired spark or arc discharge occurs in the gap. This change of the integral is relatively simple to detect and it is used to control the supply voltage.

The present invention now has for one of its main objects to provide an improved generator for electrolytic erosion processes in which arcs and sparking are largely prevented from forming and if such should occur they are rapidly extinguished.

It is a further object of this invention to provide a generator for electrolytic erosion processes in which the voltage supplied to the gap is influenced in such a manner that arc and spark discharges, if any were to occur, will be readily extinguished.

The present invention has for a further object to provide a voltage generator for electrolytic erosion processes which is of comparatively simple design and which is reliable in operation.

These and still further objects of the present invention and the entire scope of applicability thereof will become apparent from the detailed description given hereinafter; it should be understood, however, that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

In the drawings:

FIG. 1 shows the circuit diagram of a voltage generator according to the present invention,

FIG. 2 shows a modification of the circuit of FIGURE 1 and is provided with an integrator unit and means to extinguish arcing or sparking,

FIG. 3 shows the course of an impulse both in a purely electrolytic process and when undesired discharges occur.

As shown in both of the embodiments of FIGURES 1 and 2, given by way of illustration, the electrical energy required for the electrolytic erosion process is supplied by a single-phase power transformer **1**, of which the primary **1***a* may be provided with several taps **1***b* (see FIGURE 2) for the coarse adjustment of the voltage supplied at the secondary **1***c*. Connected to the secondary **1***c* is a two-way rectifier bridge comprising the individual rectifiers **2**, **3**, **4** and **5**. The pulsating direct current voltage is taken from the conductors **6** and **7** and supplied directly to the erosion gap defined by tool electrode E and workpiece W. The rectifiers **4** and **5** of FIGURE 2 are so-called controlled rectifiers which are preferably provided with a pnpn junction layer combination, whereas rectifiers **2**, **3**, **4**, **5** of FIGURE 1 may simply be conventional rectifiers known in the art. In the embodiment of FIGURE 1 the alternating current tapped from the secondary **1***c* of the transformer **1** is fed through the rectifiers **2**, **3**, **4** and **5** forming a full wave rectifier and is applied across the gap E, W. The system of FIGURE 1 is readily adapted for use when the likelihood or arcing or sparking is slight, or if the same should occur, the drop of potential of each half cycle of the voltage causes any arcing or sparking to extinguish by itself.

In the embodiment of FIGURE 2 wherein rectifiers **4** and **5** are controlled rectifiers, there is shown a system which provides for checking for the presence of arcs or sparking across the gap and for positively extinguishing the same. The system of FIGURE 2 is also readily suitable for working with higher voltages than in the system of FIGURE 1 due to controlled ignition of the rectifiers which also provides for extinguishing of undesired arcs or sparking when working with such higher voltages as will be more fully described hereinafter.

Controlled rectifiers of this type are commercially available. They possess a thyratron characteristic, i.e., they remain conductive upon single ignition until the anode potential is lowered below a critical value at least for a brief period of time. After this interruption, the main line may again be rendered conductive by igniting, i.e., transmitting an impulse to the igniting or control electrode. Selection of the ignition point enables the total energy supplied to the gap E, W to be adjusted. With a phase angle of 0° between the zero crossover of the alternating current voltage and the ignition time maximum energy is transmitted; with the phase angle increasing, the energy transmitted decreases and reaches zero at a phase angle of 180°. It may be appreciated that no smoothing condensers are arranged at the outlet side of the rectifier circuit of either FIGURE 1 or 2 so that the voltage at the end of each half cycle drops to almost zero. This causes at least a major portion of the arc or spark discharges to be extinguished.

In FIGURE 2 there is shown a circuitry arrangement which provides for eliminating the possibility that sufficient charge carriers are present at the next voltage surge for an arc to ignite again. In this embodiment of FIGURE 2, steps may be taken to apply the next voltage cycle across the gap only after a certain time lag. This delay is obtained by adjusting the ignition angle of the controlled rectifiers **4**, **5**. In order to achieve this, two resistors **8** and **9** are arranged in series with one another and parallel to the erosion gap, the resistor **9** being provided with an adjustable tap **9***a*. Inserted between the tap **9***a* of the resistor **9** and a terminal point **9***b* of the resistor **9** is a condenser **10**. The RC member comprising the resistor **9** and the condenser **10** operates as an integrator assembly or unit, i.e., the total charge stored in the condenser **10** is proportional to the time integral of the voltage across the erosion gap.

The voltage conditions appearing at the erosion gap are best understood by reference to FIGURE 3 which diagrammatically shows the characteristics of the voltage u as a function of time. The curve **11** corresponds to the voltage characteristic during normal operation, i.e., if no undesirable spark or arc discharges occur across the gap, and if the ignition angle of the controlled rectifiers **4** and **5** amounts to 0°. The curve **11** shows a half cycle of the alternating current voltage supplied by the secondary **1***c* of the transformer. However, if an undesirable spark or arc discharge occurs during a half cycle, by way of example at the moment t_1, the further voltage characteristic of this half cycle will change according to curve **11′**. The changed voltage characteristic is due to the voltage drop at the gap when such spark or arc discharges occur. Such spark or arc discharges will apply a load greater than that of a normal discharge of voltage across the gap without arcing or sparking.

It is readily to be appreciated that the area underneath the curve **11′** is smaller than that underneath the curve **11**. Since these areas correspond to the integral of the voltage characteristic, it can be seen that the integral is smaller when a spark or arc discharge takes place than in the absence of such discharges. Accordingly, the voltage across the condenser **10** is smaller when discharges occur. This fact is made use of for the control of the supply voltage received from the rectifier circuit.

For the ignition of the controlled rectifiers **4** and **5**, there is provided an ignition circuit with a double-base transistor **15**. The circuit comprising the two resistors **21** and **24** connected to the bases **28** and **27**, respectively, of transistor **15**, and the capacitor **23**, the adjustable resistor **22** connected to emitter **15***a* of the transistor **15** constitutes an impulse generator for actuating the controlled rectifiers **4** and **5**. The type of operation of the circuit is determined by the bistable characteristic of the double-base transistor **15**. If the emitter voltage of this transistor **15** is smaller than a critical emitter peak voltage, the transistor **15** blocks, i.e., the resistance between the base electrodes **27**, **28** is high. If the emitter voltage rises to emitter peak voltage or beyond, the transistor becomes conductive between the base electrodes **27** and **28**. In addition, the condenser **23** charged via the variable resistor **22** can discharge via the base **27** and the resistor **24**. After supplying the control impulse for the rectifiers **4** and **5** and discharging of the condenser **23**, the latter will again be charged via the resistor **22** until the emitter voltage is again reached at which time the path between base electrodes **27** and **28** again become conductive. The impulse supply frequency is therefore a function of the time constant of an RC member consisting of the variable resistor **22** and the condenser **23**.

The ignition impulse applied to the resistor **24** is transmitted to the control electrodes of the controlled rectifiers **4** and **5** via the resistors **26** and **25** and will cause ignition thereof at any predetermined time of a half cycle.

Two rectifiers **16** and **17** are provided for the purpose of supplying the impulse generator or ignition circuit, said rectifiers being interconnected and having their oppositely arranged terminals connected to the secondary winding **1***c* of the transformer **1**. The common terminal or connecting point **16***a* of the rectifiers **16** and **17** is connected to the conductor **20** of the ignition circuit via a resistor **18**. Arranged between the junction **7** and the conductor **20**, for the purpose of limiting the voltage through the conductor **20** relative to the reference potential at junction **7**, is a Zener diode **19**. If the actual value of the alternating current voltage appearing at the secondary **1***c* of the transformer **1** amounts, by way of example, to 100 volts, the diode **19** limits the voltage between junction **7** and the conductor **20** to about 20 volts. If the voltage at the conductor **20** rises, the voltage in the forward direction at a controlled rectifier **4, 5** connected in the same direction as the rectifiers **16, 17** will rise as well. If the voltage in the conductor **20** rises relative to junction **7**, the condenser **23** begins to charge in dependence on the adjusted value of the variable resistor **22**. The resistor **22** thus enables the ignition point for the rectifiers **4, 5** to be adjusted relative to the zero crossover of the alternating current voltage of the transformer **1**. The ignition angle of the controlled rectifiers **4** and **5** is further influenced by a npn transistor **13** which is parallel with the condenser **23**.

In normal operation, a voltage is applied between the emitter **13***a* and the base **13***b* of the transistor **13** which keeps the transistor **13** at low conductivity. If non-desired arc or spark discharges occur, the voltage at the condenser **10** will drop. This causes the influence of the negative potential of the reference voltage source **12** connecting the condenser **10** with the emitter **13***a* of the transistor **13** to be reduced so that the emitter-collector line of the npn transistor becomes more conductive. This causes the charging condenser **23** to be bridged so that the ignition impulse for the rectifiers **4** and **5** is delayed. This shunt process effected by means of the transistor **13** thus enables the ignition angle automatically to be adjusted so that the effective voltage at the gap can be lowered below the critical value in the case of arc or spark discharges.

The circuit according to the present invention is therefore distinguished by the fact that arcs will extinguish at the end of a half cycle of the alternating current voltage supplied since the supply voltage at the gap at this point actually drops to practially zero. In applications where a renewed ignition of the arc must be feared owing to residual ionization in the gap when the voltage rises, an integrator unit may be provided according to the invention which delays the renewed voltage surge at the gap if an arc has ignited during the preceding half cycle.

Having thus described the present invention what is desired to be secured by United States Letters Patent is:

1. A voltage generator, particularly for electrolytic erosion machining adapted to apply a voltage across a gap defined by a workpiece electrode and a tool electrode; comprising a source of alternating current, rectifier means in circuit with said alternating current source for supplying a direct current across said gap, ignition means in circuit with said rectifier means for controlling ignition of said rectifier means, and integrator means in circuit with said gap and said ignition means determining the presence of non-desired discharge across said gap and influencing said ignition means to control ignition of said rectifier means.

2. A voltage generator according to claim 1, wherein said rectifier means comprises at least one controlled rectifier, said ignition means in circuit with said rectifier means including adjustable delay means so that the ignition time of the rectifier can be freely selected.

3. A voltage generator according to claim 1 wherein said integrator means arranged in circuit with said ignition means comprises an RC member for determining the time integral of the voltage characteristic appearing at the erosion gap to control the ignition time of said controlled rectifier in dependence on said voltage characteristic received by said integrator means.

4. A voltage generator according to claim 2, wherein said controlled rectifier consists of at least one controlled pnpn semiconductor having a thyratron characteristic.

5. A voltage generator according to claim 2, wherein said adjustable delay means includes a variable resistor and a capacitor to permit variation of the ignition angle of said controlled rectifier to be performed and said ignition means is further provided with a double-base transistor.

6. A voltage generator according to claim 5; wherein said ignition means includes an npn transistor component controlled by said integrator means to shunt said capacitor of said adjustable delay means.

7. Voltage generator for electrolytic erosion process comprising rectifier means including controlled semiconductor rectifier components, control circuit means in circuit with said semiconductor rectifier components for controlling rectification of at least one phase alternating current, said control circuit means including delay means for delaying the ignition point of said semiconductor rectifier components, said rectified direct current being adapted to be applied across a gap defined by a workpiece electrode and tool electrode, an integrating network electrically coupled with said gap to produce a signal indicative for the occurrence of an arc or spark discharge between these electrodes, said integrating network being electrically connected to said control circuit such that the ignition of the semiconductor components is delayed upon occurrence of arc or spark discharges, to thereby reduce the direct current voltage appearing at the gap.

8. Voltage generator for electrolytic erosion process comprising rectifier means including rectifier components possessing a thyratron characteristic, control circuit means in circuit with said semiconductor rectifier components for controlling rectification of at least one phase alternating current during each half cycle, said control circuit means including delay means for delaying the ignition point of said rectifier components, said rectified direct current being adapted to be applied across a gap defined by a workpiece electrode and tool electrode, an integrating network electrically coupled with said gap to produce a signal indicative for the occurrence of an arc or spark discharge between these electrodes, said integrating network being connected to said control circuit such that the ignition of the rectifier components is delayed upon occurrence of arc or spark discharges, to thereby reduce the direct current voltage appearing at the gap.

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