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(54) POWER SUPPLY CIRCUIT FOR ELECTRIC DISCHARGE MACHINE

SPEISESCHALTUNG FÜR ELEKTROEROSIONSBEARBEITUNGSMASCHINE

CIRCUIT D'ALIMENTATION POUR MACHINE A DECHARGE ELECTRIQUE

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Description

The present invention relates generally to a power supply circuit for an electric discharge machine. More particularly, the present invention relates to a power supply circuit for an EDM machine which reduces machining current cutoff without degrading the machining current waveform.

Background of the Invention

An electric discharge machine ("EDM"), such as that described in JP-A 58-40225, has a transistor switch placed between the gap and the power source. The transistor switch is periodically turned on and off for short predetermined periods which defines a machining cycle. Within the "on" time of a machining cycle, the transistor may be intermittently triggered on and off. The intermittent turning on and off of the switching transistor maintains a generally continuous machining current.

When conditions are such that the machining current should be lowered during the predetermined "on" time, the current is cutoff. Therefore, the actual "on" time during a machining cycle is less than the predetermined value of "on" time. This premature cutting-off of the machining current results in reduced machining speed and in faster wear down of the electrodes.

JP-B 62-5733, discloses a circuit where the machining current cutoff can be eliminated by the insertion of an inductor in series with the gap. Although this inductor reduces the machining current cutoff, it also increases the time constant of the circuit. The increased time constant causes the rise time of the machining current to increase. This in turn causes a drastic reduction in the machining speed, which is the exact opposite of the desired effect.

A further Japanese Patent No. JP-B 52-19359 describes a power supply for an electric discharge machine comprising an inductor connected serially with the tool electrode of the gap. Parallel to this inductor is arranged a switchable bypass of small inductance. The bypass is used to shorten the pulse length of the machining current pulses in cutting away rise times and decay times of the currents flowing through the inductor.

Summary of the Invention

It is an object of the present invention to provide a power supply circuit for an EDM machine which reduces machining current cutoff without increasing the rise time of the machining current.

It is a further object of the present invention to provide an EDM power supply circuit which minimizes machining current cutoff without causing an undesirable increase in machining current rise time due to an inductance.

These and other objects of the present invention are accomplished by the present invention which generally relates to a power supply circuit for an electric discharge machine that periodically turns on a switching element connected between the gap and the power source. An inductor, placed in series with the gap and the power source, is shorted out of the power supply circuit during the rise time of the machining current. After the machining current rise time period is over, the inductor is switched into the circuit to reduce machining current cutoff.

Additional objects, advantages and novel features of the invention will be set forth in part in the description which follows, and in part will become apparent to those skilled in the art upon examination of the following or may be learned by practice of the invention. The objects and advantages of the invention may be realized and attained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

Brief Description of the Drawings

The accompany drawings, which are incorporated in and form a part of the specification, illustrate an embodiment of the present invention and, together with the description, serve to explain the principles of the invention. In the drawings:

FIGURE 1 is a circuit diagram showing one embodiment of the invention; and
FIGURE 2 illustrates signal wave forms at principal points in Figure 1.

Detailed Description of the Preferred Embodiment

Reference will now be made in detail to the present preferred embodiment of the invention, an example of which is illustrated in the accompany drawings.

As shown in Fig. 1, a transistor TR1 which serves as a first switching element, is connected between the power source B and gap G. A resistor R1, connected between the transistor TR1 and gap G is used for measuring the current flowing through the gap G. An inductor L is also connected in series with the gap G. A transistor TR2, which serves as a second switching element, is connected in parallel with the inductor L. A transistor TR3, diode D, and resistor R3 are connected in parallel with the combination of the current measuring resistance R1, gap G, and the parallel combination of inductor L and transistor TR2. The transistor TR3 serves as a third switching element. Transistor TR2 is just one example of a means for shorting out inductor L during the rise time of the machining current and for placing the inductor L into the circuit after the rise time.

The gates of the transistors TR1, TR2 and TR3 are respectively connected to gate signals 1, 2 and 3.

Fig. 2 illustrates the timing diagram for various signal wave forms which appear at principal points in Fig. 1. The operation of the aforementioned embodiment will now be described with reference to Fig. 2.

When the first gate signal goes high or "on" at t_o, the base voltage of transistor TR1 goes high, thereby

switching on transistor TR1. At that time, since the inter-pole gap resistance is high, the gap voltage VG is approximately equal to the power source B voltage. Also at time t_o, the third gate signal goes high, i.e., to the "on" state, thereby switching on transistor TR3 which is connected opposite to the transistor TR1 in the sense of direction of current flow. At time t_1, a certain time after t_o, the gap G begins to break down or ionize and the discharge current begins its rise time as current starts to flow in the gap G. The rise time of the discharge current is completed at time t_2.

As illustrated in Fig. 2, the transistor TR2 is turned on by the second gate signal a predetermined time t_d after the start of the rise time. During this period the transistor TR2 is switched on and the inductor L is thereby shorted out of the circuit. The inductor L is again brought back into the circuit at a time t_3, at which time the transistor TR1 is gated off and the discharge current begins its fall time.

As alluded to above, the transistor TR3 is turned on at approximately the same time as the transistor TR1 is turned on. However, the transistor TR3 is turned off a predetermined time t_d after transistor TR1 is turned off. When transistor TR1 is off and transistor TR3 is on, the electromotive force ("emf") generated by the inductor L causes current to flow through transistor TR3 and gap G. In this manner the current efficiently generates a discharge machining current.

Turning again to Fig. 1, the value of the voltage VG is indicative of the current flowing through current measuring resistance R1 and also through the gap G. The comparator C compares the gap voltage VG to a reference voltage (schematically indicated by a battery) for the comparing the gap current to a predetermined value of current. The comparator C outputs a high signal when the gap voltage VG is higher than the reference voltage, which corresponds to the gap current being below the predetermined current. The output of the comparator C and the first gate signal are input to an AND gate 10. The output of the AND gate 10 drives the base of the transistor TR1 for switching the transistor on and off. Thus, when the AND gate 10 receives a high first gate signal, but the gap voltage VG is lower than the reference voltage, the AND gate 10 outputs a gate signal to switch off transistor TR1. Only when the first gate signal is high and the gap voltage VG exceeds the reference voltage, corresponding to the gap current being below the predetermined value of current, will the gate output a high gate signal to the base of transistor TR1.

During the discharge current rise time t_d ($t_d = t_2 - t_1$), the transistor TR2 is turned on and inductor L is shorted out of the circuit. Therefore, during the time t_d inductor element L does not add to the time constant of the circuit. Consequently, it does not effect the rise time of the discharge current.

At the end of the discharge current rise time, i.e. at $t = t_2$, the second gate signal is turned off, thereby turning off transistor TR2. At this time, the inductor L is connected in series with the gap G and the power supply B. With the inductor L in the circuit, the discharge current (machining current) tends to smooth out, thereby preventing current spikes which cause the machining current to cutoff.

When the first gate signal goes to the "off" state at time t_3, the second gate signal is switched "on" so that transistor TR2 is turned "on". By turning "on" transistor TR2, the inductor L is effectively removed from the circuit, thus allowing the discharge current to fall rapidly. The third gate signal is switched to the "off" state after a time delay t_d following the transition of the first gate signal to the "off" state. The transistor TR3 is kept on during this time delay period t_d in order to prevent damage to the transistor TR1 from a reverse emf.

As should now be understood by the artisan, during the "on" time of the machine, i.e., between the times t_2 and t_3, the transistor TR1 is repeatedly switched "on" and "off" at high speeds, by the signal from the AND gate 10 in order to maintain an almost constant flow of discharge current through the gap G. Also during this time, an emf is developed across inductor element L whenever the transistor TR1 is switched "off". With the transistor TR1 off, discharge current flows through resistor R3, diode D, transistor TR3, current measuring resistor R1, and gap G. Thus, even when transistor TR1 is switched off, discharge current still flows through gap G. The emf developed across the inductor L is another reason why the discharge current does not cutoff.

Various modifications to the embodiment of Fig. 1 may be made. For instance, other types of current measurement means may be used in place of the current measuring resistance R1 for measuring the gap current. Also, other types of switching elements may be used in place of transistors TR1, TR2 and TR3. Additionally, transistor TR3 may be deleted from the embodiment of Fig. 1.

Through the power supply circuit of the present invention, the machining current is prevented from being cutoff without increasing the rise time of the current while maintaining machining speed.

Claims

1. Power supply circuit for an electric discharge machine,
   wherein said discharge machine comprises a power source (B) and a gap (G) between an electrode and a workpiece to be machined,
   wherein said power supply circuit comprises

   - a first switching element (TR1) connected between the power source (B) and the gap (G) and controllable into an on and into an off condition,
   - an inductive element (L) connected in series with the first switching element (TR1) and the gap (G), and

- a bypass (TR2) for the inductive element (L) switchable on and off,
  characterized by
- means for intermittently switching the first switching element (TR1) into its on and off conditions, and
- means for causing discharge currents created by the electromotive force of the inductive element (L) to flow through the gap (G).

2. Power supply circuit according to claim 1,
characterized in
that said means for intermittently switching comprise means (R1) for measuring the strength of a current flowing through the gap (G), a comparator (C) for said strength measured and a succeeding AND gate (10).

3. Power supply circuit according to claim 2,
characterized in
that said means for measuring is a resistor (R1) serially connected to the gap (G).

4. Power supply circuit according to claim 3,
characterized in
that said means for causing discharge currents comprise a second switching element (TR2) controllable into an on and into an off condition and being connected between the inductive element (L) and said resistor (R1).

5. Power supply circuit according to claim 4,
characterized by
a diode (D) serially connected to the second switching element (TR3).

6. Power supply circuit according to claim 4,
characterized in
that the first and the second switching element are transistors (TR1, TR3) being connected one to the other in opposite directions.

7. Method for operation of a power supply circuit according to one of the preceding claims,
characterized in
that the first (TR1) and the second switching element (TR3) are switched on coincidently at a start time (t0),
that the bypass (TR2) is switched off after the rise time (t2) of a discharge current through the gap (G),
that the first switching element (TR1) is switched off and the bypass (TR2) is switched on coincidently at a stop time (t3),
that the second switching element (TR3) is switched off after the decay time (t4) of said discharge current, and
that said means for intermittently switching the first switching element (TR1) switches this element (TR1) to its on condition when said gap current is less than a predetermined second current and switches this element (TR1) to its off condition otherwise.

Patentansprüche

1. Stromversorgungsschaltung für eine Funkenerosionsmaschine, wobei die Funkenerosionsmaschine eine Stromquelle (B) und einen Bearbeitungsspalt (G) zwischen einer Elektrode und einem zu bearbeitenden Werkstück aufweist,
wobei die Stromversorgungsschaltung

   - ein erstes Schaltelement (TR1) aufweist, welches zwischen der Stromquelle (B) und dem Bearbeitungsspalt liegt und durchgesteuert und gesperrt werden kann,
   - ein induktives Element (L), welches mit dem ersten Schaltelement (TR1) und dem Bearbeitungsspalt in Reihe geschaltet ist, sowie
   - einen Bypass (TR2) für das induktive Element (L), der ein- und ausschaltbar ist,
     gekennzeichnet durch
   - Mittel zum intermittierenden Ein- und Ausschalten des ersten Schaltelements (TR1), und
   - Mittel, um von der elektromotorischen Kraft des induktiven Elements (L) erzeugte Entladungsströme durch den Bearbeitungsspalt (G) fliessen zu lassen.

2. Stromversorgungsschaltung nach Anspruch 1, dadurch gekennzeichnet, dass die genannten Mittel zum intermittierenden Schalten Mittel (R1) zur Messung der Stärke eines durch den Bearbeitungsspalt (G) fliessenden Stroms, einen Komparator (C) für die gemessene Stromstärke und ein darauffolgendes UND-Tor (10) aufweisen.

3. Stromversorgungsschaltung nach Anspruch 2, dadurch gekennzeichnet, dass das genannte Messmittel ein Widerstand (R1) ist, der mit dem Bearbeitungsspalt (G) in Reihe geschaltet ist.

4. Stromversorgungsschaltung nach Anspruch 3, dadurch gekennzeichnet, dass das Mittel zur Erzeugung von Entladungsströmen ein zweites Schaltelement (TR2) aufweist, welches durchgesteuert und gesperrt werden kann und zwischen dem induktiven Element (L) und dem Widerstand (R1) liegt.

5. Stromversorgungsschaltung nach Anspruch 4, gekennzeichnet durch eine Diode (D), welche mit dem zweiten Schaltelement (TR3) in Reihe geschaltet ist.

6. Stromversorgungsschaltung nach Anspruch 4, dadurch gekennzeichnet, dass das erste und das zweite Schaltelement Transistoren (TR1, TR3) sind, welche in Gegenrichtung miteinander verbunden sind.

7. Verfahren zum Betrieb einer Stromversorgungsschaltung nach einem der vorstehenden Ansprüche, dadurch gekennzeichnet, dass das erste (TR1) und das zweite Schaltelement (TR3) zu einem Startzeitpunkt (t0) gleichzeitig eingeschaltet werden, dass der Bypass (TR2) nach der Anstiegszeit (t2) des durch den Bearbeitungsspalt (G) fliessenden Entladungsstroms ausgeschaltet wird, dass das erste Schaltelement (TR1) zu einem Stop-Zeitpunkt (t3) ausgeschaltet und der Bypass gleichzeitig eingeschaltet wird, dass das zweite Schaltelement (TR3) nach der Abfallzeit (t4) des Entladungsstroms ausgeschaltet wird, und dass das Mittel zur intermittierenden Schaltung des ersten Schaltmittels (TR1) dieses Element (TR1) durchschaltet, sobald der der Spaltstrom kleiner ist als ein bestimmter zweiter Strom, und dieses Element (TR1) andernfalls sperrt.

Revendications

1. Circuit d'alimentation pour une machine d'électroérosion, ladite machine d'électroérosion comprenant une source d'énergie (B) et un gap (G) disposé entre une électrode et une pièce à usiner,
ledit circuit d'alimentation comprenant

   - un premier élément commutateur (TR1) connecté entre la source d'énergie (B) et le gap (G) et dont la condition passante et bloquée est capable d'être commandée,

   - un élément inductif (L) connecté en série audit premier élément commutateur (TR1) et au gap (G), et

   - une dérivation (TR2) pour l'élément inductif (L), capable d'être enclenchée et déclenchée, caractérisé par

   - des moyens pour la commutation intermittente des conditions enclenchée et déclenchée dudit premier élément commutateur (TR1), et

   - des moyens pour faire passer par le gap (G) des courants de décharge créés par la force électromotrice de l'élément inductif (L).

2. Circuit d'alimentation selon la revendication 1, caractérisé en ce que lesdits moyens de commutation intermittente comprennent des moyens (R1) pour mesurer l'intensité d'un courant qui passe par le gap (G), un comparateur (C) pour ladite intensité mesurée et un circuit ET (10) successif.

3. Circuit d'alimentation selon la revendication 2, caractérisé en ce que lesdits moyens de mesure sont constitués d'une résistance (R1) connectée en série au gap (G).

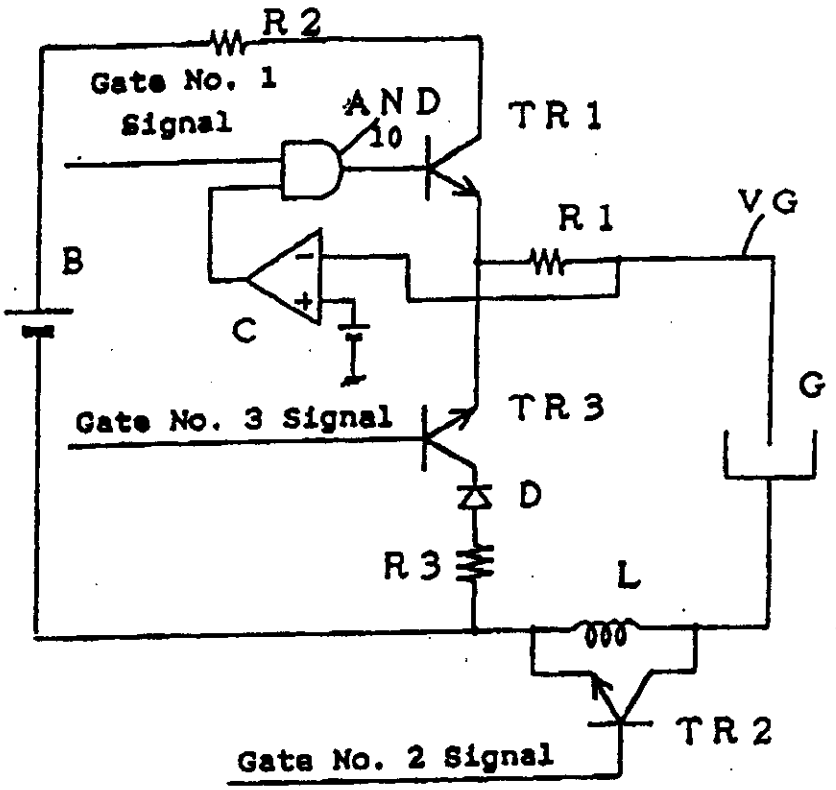
4. Circuit d'alimentation selon la revendication 3, caractérisé en ce que lesdits moyens produisant des courants de décharge comprennent un deuxième élément commutateur (TR2) dont la condition passante est bloquée est capable d'être commandée et qui est connecté entre ledit élément inductif (L) et ladite résistance (R1).

5. Circuit d'alimentation selon la revendication 4, caractérisé par une diode (D) connectée en série audit deuxième élément commutateur (TR3).

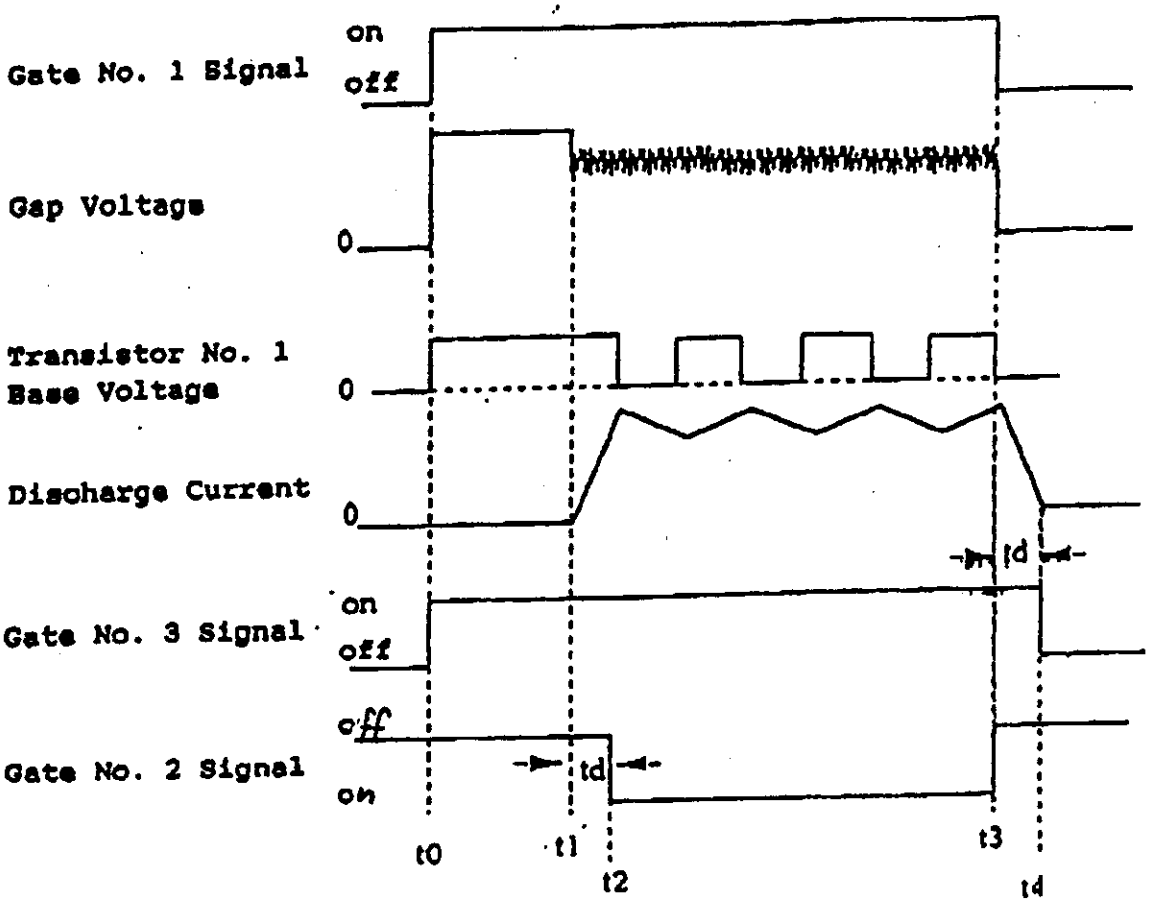
6. Circuit d'alimentation selon la revendication 4, caractérisé en ce que le premier et le deuxième élément commutateur sont des transistors (TR1, TR3) mutuellement connectés en directions opposées.

7. Procédé d'opération d'un circuit d'alimentation selon l'une des revendications précédentes, caractérisé en ce que le premier (TR1) et le deuxième élément commutateur (TR3) sont enclenchés simultanément à un temps de départ (t0), que la déviation (TR2) est déclenchée après le temps de montée (t2) d'un courant de décharge passant par le gap (G), que le premier élément commutateur (TR1) est déclenché et la déviation (TR2) est enclenchée simultanément à un temps d'arrêt (t3), que le deuxième élément commutateur (TR3) est déclenché après le temps de chute (t4) dudit courant de décharge, et que lesdits moyens de commutation intermittente du premier élément commutateur (TR1) mettent cet élément (TR1) en condition passante lorsque ledit courant de gap est inférieur à un deuxième courant déterminé et mettent ledit élément (TR1) en condition bloquée lorsque ce n'est pas le cas.

Fig,1


R 2
Gate No. 1
Signal
AND
10
TR 1
R 1
VG
B
C
G
Gate No. 3 Signal
TR 3
D
R 3
L
TR 2
Gate No. 2 Signal

Fig,2


Gate No. 1 Signal
on
off
Gap Voltage
0
Transistor No. 1
Base Voltage
0
Discharge Current
0
td
Gate No. 3 Signal
on
off
Gate No. 2 Signal
off
on
td
t0
t1
t2
t3
td

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