

May 2, 1961

D. M. YENNI ET AL
ELECTRIC ARC SPRAYING

2,982,845

Filed July 11, 1958

Fig. 1.

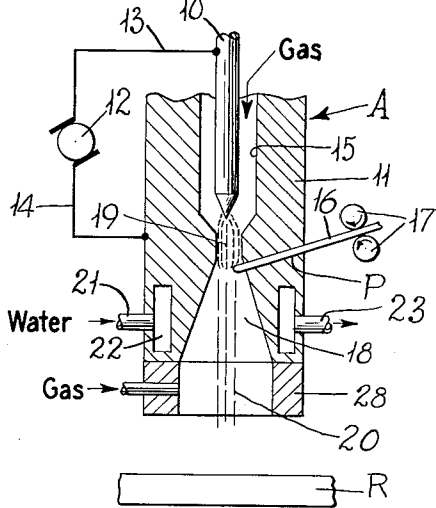


Fig. 2.

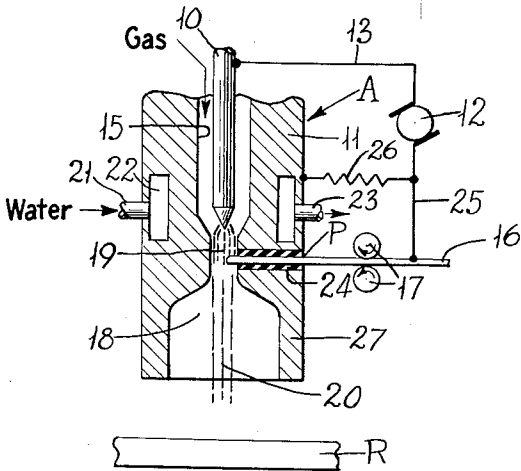
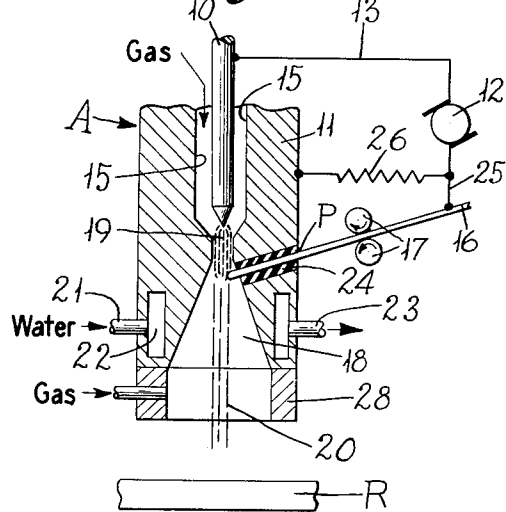


Fig. 3.

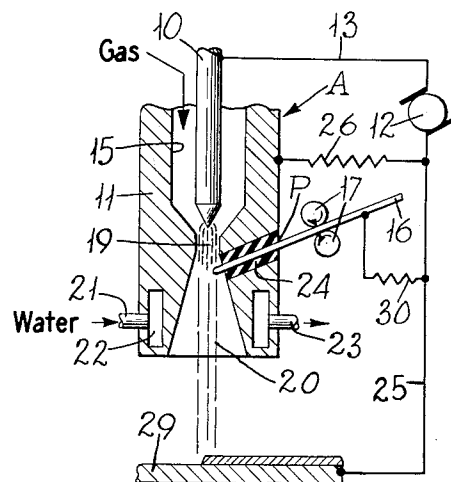


Fig. 4.

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2,982,845

ELECTRIC ARC SPRAYING

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Filed July 11, 1958, Ser. No. 747,938

12 Claims. (Cl. 219—76)

This invention relates to electric arc spraying and, more particularly, to transforming material in the form of a rod or wire to a spray.

According to the invention, arc torch wire spraying is accomplished by specifically feeding a consumable wire electrode into the collimated arc effluent inside of the nozzle of the spraying equipment. In this fashion the consumable wire is positioned in an area of maximum or near maximum concentration of momentum thus resulting in a desirably fine droplet spray of molten coating or welding material. The portion of the nozzle extending beyond the point of wire feed tends to focus and control the droplet spray. The consumable wire electrode can be in electrical contact with the nozzle electrode and thereby receive its electrical power.

It is preferred in some cases that the consumable wire electrode be electrically insulated from the nozzle electrode in order to maintain higher power to the wire and to take advantage of resistance heating in the wire to increase wire melt-off. It is also preferred that torches having the nozzle section extending downstream from the wire have a diverging nozzle so as to minimize plugging and to reduce possible arc pitting of the nozzle at high current levels.

There is a need in industry for improved methods of conveniently applying metal to clad various workpiece surfaces and to weld articles together. One means previously employed has been to use a high pressure arc process of the type disclosed in Patent No. 2,847,555, based on application, Serial No. 539,870, filed on October 11, 1955, by Donald M. Yenni. In such process an arc was struck between a nonconsumable stick-type electrode, such as thoriated tungsten, and a consumable metal wire electrode. A gas stream, relatively inert to the non-consumable electrode, passed along this electrode and flowed through a gas nozzle positioned between the stick electrode and the consumable electrode. The combination of the gas flow and nozzle stabilized and collimated the arc energy. The jet-like effluent from the nozzle outlet protects and projects the molten metal from the consumable electrode toward the desired workpiece area. Use of inert gas streams enables the molten metal to be protected from air contamination and results in relatively oxide-free metal deposits having desirable adherent characteristics.

Such process and apparatus have been greatly improved, according to this invention, by specifically feeding the consumable wire electrode into the collimated arc effluent inside of the gas nozzle. This novel method has the primary advantages of improved control over the focusing, positioning, and droplet quality of the molten metal spray. The wire is preferably positioned at or near the point of minimum nozzle cross section thus resulting in maximum or near maximum momentum transfer from the hot high velocity arc gas to the molten coating material.

In the drawing:

Fig. 1 is a fragmentary view mainly in vertical cross

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section of apparatus illustrating one form of the invention; and

Figs. 2, 3, and 4 are similar views of modifications.

As shown in Fig. 1, apparatus A includes a stick electrode 10 positioned in coaxial relation to a nozzle electrode 11. Such electrodes are connected to an electric power supply 12 through leads 13 and 14, respectively. A selected gas stream flows down through the annular space between stick electrode 10 and bore 15 in nozzle electrode 11. Such gas may be any suitable arc gas such as argon, helium, nitrogen, or hydrogen. Some hydrogen in the gas mixture is desired where hydrogen is metallurgically acceptable to increase the wire melt-off, because of increased heat created by the generation of atomic hydrogen in the arc, and its subsequent recombination on or near the spraying material.

A consumable wire 16 is fed by rolls 17 through a lateral passage P in the wall of nozzle electrode 11 and into the nozzle passage 18. The wire is shown entering at an acute angle to the horizontal, but this is only a convenience. The vertical position at which the wire enters is chosen at a point most satisfactory for given equipment size and configuration. The wire thus is positioned as close as possible to the point of maximum arc constriction and maximum momentum concentration. The wire 16 is in electrical contact with nozzle electrode 11 and thus may become an electrode when it projects into nozzle passage 18. The arc 19, which originally passed between electrodes 10 and 11, then tends to transfer in part to wire 16. The molten metal from wire 16 is then projected as a high velocity effluent 20 with the gas stream. The nozzle 11 is cooled below its melting point by passing cooling fluid such as water from inlet 21 through passage 22 to outlet 23. A suitable receiver R is disposed under the apparatus A in the zone into which the spray-containing effluent 20 is discharged.

The wire feed rate is adjusted in combination with the electrical power to maintain the molten tip of the wire in approximately the center of the nozzle passage. This results in the metal spray being approximately in line with the longitudinal axis of the nozzle passage 18. Too slow a feed rate results in a spray of large particles at an angle to such axis, such angle being located on the side in the direction from which the wire is fed. Increasing the feed rate beyond optimum conditions results in the same spray as with too little feed, except the spray is located on the other side of such axis. Both of these conditions are obviously undesirable.

Ideal wire feed rates of 250 inches/minute for steel 140 inches/minute for Nichrome V, and 300 inches/minute for aluminum have resulted with $\frac{1}{16}$ -inch diameter wire and 10 kw. D.C.S.P. total power. The equipment used for the above conditions had a nozzle throat of $\frac{1}{8}$ -inch diameter, and a divergent bore of 30° included angle.

In the modification of Fig. 1 the nozzle electrode and the consumable wire are at the same electrical potential. Such circuit arrangement enables an effective self-regulation to occur in connection with the wire feed which tends to maintain the molten tip of the wire in the approximate center of the nozzle passage. As the wire projects into the longitudinal nozzle passage, it begins to carry increased amounts of current. If it projects beyond the center of the passage, the increased current plus resistance heating along the projected portion of the wire, plus greater exposure to the high energy stream, increases the melt-off rate, and the wire melts more rapidly back toward the center position. If the wire feed rate slows up and the wire projection decreases, the wire will draw less current and the nozzle electrode will draw more current. The overall effect will be to reduce melt-off rate.

The longitudinal nozzle passage extending beyond the wire is effective to focus and control the position of the

molten droplet stream. The divergent discharge passage is effective to reduce undesirable plugging caused by deposits of molten metal particles within the nozzle. A divergent passage in the nozzle electrode also spreads the electrode area and reduces current density. This helps reduce erosion at high current levels. A divergent passage in the nozzle electrode also allows supersonic outlet gas velocity to be attained under certain conditions which further accelerates the molten material in the spray to produce higher impact on workpieces and more dense coatings or welds. For the above reasons, it is, therefore, preferred that the nozzle outlet have an increased cross-sectional area, as compared to the area of the nozzle at the point of wire entry.

Additional gas shielding to minimize atmospheric air contamination of the effluent is obtained by introducing shielding gas at the nozzle outlet through a hollow feed device 28 in the shape of the outlet end of the nozzle.

Presently preferred modification of the present invention is shown in Fig. 2. In this form the consumable wire electrode 16 is electrically insulated from nozzle electrode 11 by a tubular electrical insulator 24 mounted in the lateral passage P. The main electrical connections from arc power supply 12 are through line 13 to the stick electrode 10 and line 25 to the consumable wire 16. The nozzle electrode 11 is connected to the power supply through a resistance 26 which tends to maintain the nozzle at a lower potential than that of the consumable wire.

This apparatus, Fig. 2, may be operated at higher wire feed rates than that of Fig. 1, because higher power levels can be maintained to the wire without damage to the nozzle. This becomes important when wire feed rates as high as 100 lbs./hr. or higher are desired. A pilot arc is maintained between the stick electrode and the nozzle electrode to effect start-up of the process and also to maintain an arc if wire feed ceases for any reason. The electrical contact from lead 25 to wire 16 may be positioned externally to the torch in order to increase resistance heating along the wire.

In the modification of the invention shown in Fig. 3, nozzle extension 27 serves the same purpose as the extended nozzles of Figs. 1 and 2, namely, to help focus and direct the gas-molten particle stream to a desired point or area and to minimize air contamination of the molten particles.

A further modification of the invention is shown in Fig. 4. The arc current from electrode 10 is divided among nozzle anode 11, consumable wire electrode 16, and workpiece 29 by suitable adjustment of ballast resistors 26 and 30.

The following examples describe actual use of this invention to apply metal coatings to metallic base plates:

EXAMPLE I

Arc torch spraying of Nichrome wire

Apparatus of the type shown in Fig. 1 was used with the exception that a straight bore nozzle was used, i.e., non-divergent outlet. A gas mixture of 200 c.f.h. argon and 13.5 c.f.h. hydrogen passed down around a 1/8-inch diameter thoriated tungsten stick electrode and out through a 1/8-inch diameter (non-divergent) passage in the nozzle electrode. An arc of 75 volts (D.C.S.P.) and 150 amperes was struck between such electrodes. A 1/16-inch diameter Nichrome V wire was fed through a passage in the side of the nozzle at 40 inches/minute. Additional hydrogen shielding gas at 50 c.f.h. was introduced at the nozzle outlet. The hot gas effluent and molten metal spray from the wire electrode were then impinged on a rotating 1/2-inch diameter cold-rolled steel round positioned 1-inch from the torch nozzle outlet. The resulting Nichrome-on-steel coating was dense, adherent, had less than one percent porosity, and less than one percent oxide impurity.

EXAMPLE II

Arc torch spraying of steel wire

Apparatus of the type shown in Fig. 2 was used. A gas mixture of 200 c.f.h. argon and 14 c.f.h. hydrogen passed down around the 1/8-inch diameter thoriated tungsten stick electrode and out through the passage in a nozzle electrode having a 1/8-inch diameter throat and a divergent outlet having 30° angle. An arc of 80 volts (D.C.S.P.) and 110 amperes was struck between the stick electrode and the consumable wire electrode plus nozzle electrode. The consumable wire electrode carried 100 amperes while an arc current of 10 amperes was supplied to the nozzle electrode. The consumable wire electrode was 1/16-inch diameter carbon steel welding rod fed at 175 inches/minute. Additional hydrogen shielding gas at 50 c.f.h. was introduced at the nozzle outlet. The hot gas effluent and molten metal spray from the consumable wire electrode were then impinged on a rotating 1/2-inch diameter carbon steel round R positioned 1-inch from the torch nozzle. The resulting steel-on-steel coating was dense, adherent, had less than 5 percent porosity and less than 1 percent oxide impurity.

The cross-sectional shapes of the nozzle passages described above are circular, but other shapes, such as rectangular, square, or oval, for example, may be used without departing from the invention.

What is claimed is:

1. Electric arc spraying apparatus comprising, in combination, a nonconsumable electrode, a nozzle electrode having a nozzle passage containing an arc constricting orifice, means for energizing a high pressure arc between said electrodes, means for supplying gas under pressure to said nozzle passage whereby a wall-stabilized arc effluent is discharged from said nozzle passage, and means for introducing a consumable wire laterally into said nozzle passage, such wire being fed into the nozzle passage between the inlet to the constricting orifice and the outlet of the nozzle passage, said arc acting to melt the end of such wire as it is fed thereto, and the so-melted metal is projected by and with said effluent in the form of a spray.

2. Electric arc spraying apparatus, as defined by claim 1, including means positioned at the outlet of the nozzle passage for introducing a separate stream of shielding gas to protect the spray effluent from the atmosphere, said means comprising a hollow feed device in the shape of the outlet end of the nozzle.

3. Electric arc spraying apparatus, as defined by claim 1, in which such wire is fed into the nozzle passage at the point of maximum constriction, whereby maximum effective momentum transfer takes place from the arc plasma and gas flow to the melted metal causing minimum particle size and maximum acceleration of the so-produced spray.

4. Electric arc spraying apparatus, as defined by claim 1, in which such wire is fed into the nozzle passage adjacent to the point of maximum constriction, whereby substantial effective momentum transfer takes place from the arc plasma and gas flow to the melted metal causing reduction in particle size and substantial acceleration of the so-produced spray.

5. Electric arc spraying apparatus, as defined by claim 1, including means insulating said wire from said nozzle electrode within such lateral wire passage, and means for energizing an arc between the end of said wire and said nonconsumable electrode of higher potential than that between said nozzle electrode and said nonconsumable electrode.

6. Electric arc spraying apparatus, as defined by claim 5, including means for energizing another arc between a workpiece and said nonconsumable electrode to increase the effective heating of such workpiece.

7. Electric arc spraying apparatus, as defined by claim

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1, in which said wire is fed into such effluent at an acute angle thereto.

8. Electric arc spraying apparatus, as defined by claim 1, in which said wire is fed into such effluent at a right angle thereto.

9. Electric arc spraying apparatus comprising a nozzle electrode having a gas inlet leading to an arc constricting orifice which discharges in a divergent outlet, a nonconsumable electrode mounted so as to project into such gas inlet in spaced relation to such orifice, means for energizing a high pressure arc between said electrodes, means for supplying gas under pressure to said inlet, whereby a wall-stabilized arc effluent is discharged through said divergent outlet, said nozzle having a lateral wire passage leading to said outlet adjacent such orifice, and means for feeding a consumable wire into such effluent therethrough.

10. Process of arc spraying which comprises energizing a high pressure arc consisting of an arc plasma and gas flow between the ends of consumable and nonconsumable electrodes, wall-stabilizing at least a portion of such arc to produce a jet-like effluent by passing it through a nozzle passage having a constricted orifice portion, and feeding the consumable wire electrode laterally into such nozzle passage and arc at a point adjacent such constricted and wall-stabilized portion thereof, producing a spray of melted wire metal which is projected by and in such effluent, whereby substantial effective momentum transfer takes place from the arc plasma and gas flow to the melted metal causing substantial acceleration of the so-produced spray.

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11. Process of arc spraying which comprises laterally constricting a high pressure arc consisting of arc plasma and gas flow, and feeding a consumable metal wire electrode laterally into such arc at the zone of such constriction producing a spray of melted wire metal, whereby maximum effective momentum transfer takes place from the arc plasma and gas flow to the melted metal causing maximum acceleration of the so-produced spray.

12. Electric arc spraying apparatus comprising a nozzle electrode having a gas inlet leading to an arc constricting orifice which discharges in a divergent outlet, a nonconsumable electrode mounted so as to project into such gas inlet in spaced relation to such orifice, means for energizing a high pressure arc between said electrodes, means for supplying gas under pressure to said inlet, whereby a wall-stabilized arc effluent is discharged through said divergent outlet, said nozzle having a lateral wire passage leading to such orifice, and means for feeding a consumable wire into such effluent therethrough.

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