BRUSH ELECTRODE ASSEMBLY FOR CONSUMABLE ELECTRODES

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FIG. 1

FIG. 3

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ABSTRACT OF THE DISCLOSURE

An electrode brush assembly including an annular cylinder body having a plurality of peripherally spaced, radially extending cylinder bores each containing a piston movable along the axis of the bore. A brush electrode is secured to each of the pistons and is movable therewith to define a dimensionally variable central aperture through the cylinder body for the consumable electrode. A cooling manifold mounted at an end of cylinder body has internal annular passages for cooling the brush electrode assembly. The pistons are actuated from a common source of compressible fluid to yieldably force the brush electrodes into sliding contact with the surface of the consumable electrode. An accumulator is connected intermediate the fluid source and pistons to provide substantially constant pressure applied to the brush electrodes against the consumable electrode surface.

Background of the invention

This invention relates to electrode brushes of the type used to supply electrical current to consumable electrodes, such as the anode in a high intensity arc electrode configuration. In particular, the invention relates to an improved electrode brush assembly for supplying electrical current to such consumable electrodes, in which it is desired to maintain a substantially constant contact pressure of the electrode brushes against the surface of the consumable electrode, regardless of cross-sectional deformities of the consumable electrode.

In electrical arc furnaces and other high intensity arc processes, such as carbothermic reduction of consumable electrode materials, the consumable electrode, which is usually the anode, must be continuously advanced into the arc region, while simultaneously being revolved. Processes of this type, of course, require suitable means for not only continuously advancing, but also for supplying electrical current to the anode. Generally, electrical current is supplied to the moving electrode through one or more electrical brushes which slidably engage the surface of the advancing anode.

Basically, it is important that the brush electrodes contact the anode surface with a force sufficient to provide an electrical connection of low resistance, but not exceeding the torsional limits of the anode or load capabilities of the electrode advancing mechanism.

In some cases, the electrical brushes are mechanically linked to an actuating mechanism, such as linkages, springs, etc., which forcibly urge the brush electrodes against the advancing electrode surface. Experience has determined, however, that brush electrode assemblies of this type are not well suited for high intensity arc processes in which the brush electrode assembly itself is positioned in close proximity to the arc, where it is exposed to extremely high temperatures. In many processes, for example, it is necessary that the brush electrode assembly be located within a few inches of the burning arc region. Accordingly, mechanical failures and other inoperabilities of purely mechanical systems have been experienced.

In some known brush electrode assemblies, the electrodes are operated hydraulically through individual hydraulic pistons mounted on the outside of a supporting member, and may operate in conjunction with springs to supply the required contact force of the individual brush electrodes against the advancing and rotating anode surface. In yet other known arrangement, the brush electrodes are forced against the consumable electrode surface by pumping an incompressible liquid, such as cooling water, into the center of an axially expansible metal shelve, the movable end of which is secured to the brush electrode. This latter arrangement is shown, for example, in U.S. Patent No. 2,899,667 to Bredtschneider et al.

In all such known brush electrode arrangements, however, the brush electrodes are maintained in contact with the moving consumable electrode surface either purely by direct mechanical linkages, springs, etc., or the brush electrodes, once engaged, do not readily yield to deformities or irregularities in the consumable electrode so that, for example, periodic increases and decreases in the applied contact pressure result as the anode rotates. As a consequence, excessive brush electrode wear occurs as the contact pressure is increased over some desired amount, and the electrical contact resistance between the brush electrodes and the anode surface increases as the contact pressure falls below optimum.

Summary of the invention

In accordance with the present invention, the individual brush electrodes are secured to pistons disposed in cylinder bores peripherally spaced about an annular cylinder body and radially movable with the pistons relative to the axis of the consumable electrode. The brush electrodes thus define a dimensionally variable central aperture through which the consumable electrode is received. The assembly includes means for cooling the cylinder body and the brush electrodes with a circulating fluid coolant and, in a particular embodiment, may comprise a cooling manifold having independent inlet and outlet passages which are interconnected through flexible conduit to cooling passages in the brush electrodes. A source of compressible fluid, such as air, is connected to operate the pistons carried in the cylinder body bores so that the brush electrodes are yieldably forced against the consumable electrode surface. Since the pistons are operated from a source of compressible fluid, the pressure acting against the pistons is substantially constant, even though movement of the brush electrodes and pistons may occur due to deformities and irregularities in the consumable electrode. In this regard, in a specific embodiment of the invention, an accumulator may be employed between the source of compressible fluid and the pistons, the accumulator having a volume which is substantially greater than the combined displacement of chambers formed between the pistons and piston guides received within axial piston recesses, so that pressure variations due to piston movement is essentially eliminated.

For a better understanding of these and other aspects of the invention, together with the objects and further advantages thereof, reference should be made to the following detailed description of exemplary embodiments, and to the drawings in which:

Drawings

FIGURE 1 is a plan view of an electrical brush assembly in accordance with the invention;
FIGURE 2 is an elevational view in cross-section of the brush electrode assembly, taken generally along the line 2—2 in FIGURE 1; and
FIGURE 3 is a schematic rendition of the brush assembly and compressible fluid supply system, including an enlarged cross-sectional view of the piston and cylinder head mechanism shown in FIGURE 2.
Description of preferred embodiment

Turning now to the drawings, the high intensity brush electrode assembly includes an annular cylinder body 10 which surrounds a consumable electrode 12 (shown in phantom) to which electrical current is to be supplied. Equally spaced peripherally about the body 10 and extending radially therethrough are a series of diametrically opposed cylinder bores 14, as best seen in FIGS. 2 and 3. Secured by screws 15 to one end of the cylinder body 10 and forming annular cooling manifold 16 having concentric annular inlet and outlet coolant passages 18, 20 connected to a respective cooling inlet tube 22 and outlet tube 24. The internal cooling passages in the manifold are independent of one another, and are interconnected only by a coolant flow path through the individual brush electrodes, as will be developed shortly.

At the other end of the cylinder body is a further cooling manifold 26 (FIG. 2) having an annular cooling passage 28 which is connected for straight-through flow of coolant, e.g., water, entering an inlet conduit 29 and exiting from the conduit 30.

Referring to FIGURES 1 and 3, each of the cylinder bores 14 in the annular cylinder body 10 contains a piston cylinder head assembly 32 for actuating in the radial direction the current-carrying brush electrode 34, which may be either moved into engagement with the surface of the anode 12 or retracted, as will be explained. As best observed in FIGURE 1, the brush electrodes 34 are disposed peripherally about the cylinder body 10 in three diametrically opposed pairs. Each of the brush electrodes is formed by a metal brush shoe holder 35 providing a dove-tail groove 35a fitting a complementary projection on a graphite brush shoe 36, holding the graphite shoe 36 firmly in place but permitting replacement of worn brush shoes by forcibly sliding the shoe along the groove 35a. The shoe-contacting area 36a of the shoe is curved to conform to the nominal curve of the anode surface and preferably is deformable to a degree permitting it to contact the anode surface over the full area of the graphite surface at all times.

Each of the shoe holders 35 is provided with a continuous cooling passage 37 (FIGURE 2) which communicates at either end with a respective inlet tube 38 and outlet tube 39 silver soldered or otherwise suitably fastened to the holder 35. Connecting fittings 38a, 39a, in turn, connect the tubes 38 and 39 for connection to flexible conduits 40, 42, which fasten to the cooling manifold 16 through fittings 43, 44 to carry the cooling fluid between the brush electrode and the inlet and outlet passages 18, 20. When a coolant is connected under positive pressure to the inlet tubes 22, 29, therefore, coolant fluid flow is established through the manifold inlet passage 18 and anode flexible conduits 40 into the brush electrode cooling passages 37. Return paths for the coolant are provided through the flexible conduits 42 and manifold outlet passage 20 to the outlet tube 24. Meanwhile, coolant is continuously circulated through the passage 28 in the second manifold 26, exiting from the conduit 30.

Electrical connections to the brush assembly are made to any of the coolant supply tubes, for example, so that the entire unit is made electrically active. Current flow, in this instance, is through the cooling manifold 16, and flexible conduits 40, 42 and assemblies 32 to the brush electrodes 34. Because the conduits and manifolds are water-cooled, all conductive parts of the entire unit can be made to carry an appreciable amount of current without over-heating and the total current is distributed substantially equally among the electrodes and associated connecting conductive elements.

The bottom of the piston and cylinder head assembly 32 may be seen best in FIGURE 3. Each assembly includes a cylinder head 46 suitable secured, as by screws, to the cylinder body 10, which supports a piston guide, or mandrel 48, provided with a passage 50 extending to its inner end from a point outside the head 46. A cylindrical piston 52 containing a bored axial recess 53 surrounding the guide 48 is slidably received in the cylinder bore 14 to form at the end of the guide a small chamfer 54 communicating with the passage 50. In a typical brush electrode assembly of the construction shown, the guide 48 may have a total length of about 1.5 inches, with the nominal outside diameter of the guide being somewhat smaller than the bored piston recess 53 machined to about .375 inch. There is sufficient clearance between the guide and piston bore to permit passage of air to the ring-like area 54 of piston 52. The opposite end of the piston 52 is of reduced diameter and is securely mounted to the brush shoe holder 35 and the ring-like area 54 of piston 52 in the bore 14 effects a corresponding radial movement of the brush electrode assembly 34 toward or away from the anode 12. Communicating with the small passage 50 through the mandrel 48 is a tube 56 (FIG. 2) which connects to a larger ring manifold 58 through which the cooled air flows, e.g., in a manifolds from source 60, which may be an air pump. An accumulator 62, which may be about two cubic feet in capacity, is joined to the line supplying air to the ring manifold 58 so that pressure surges brought about by movement of the pistons 52 or by pressure fluctuations of the source 60 are largely absorbed. The air pump or combination gas pumps serving as fluid source 60 may be implemented to provide pressure or vacuum to line 58 for bidirectional piston activation.

Seals 64 in the cylinder head and piston abut the cylinder bore 14 to prevent air leakage to the atmosphere from the cylinder bores. For purposes of assembly, the guide 48 is provided with a small groove 65 in its circumferential surface to accommodate a locating key 66 fastened to and movable with the piston 52. The pin 66 prevents rotation of the cylinder 52 within the bore, and therefore maintains alignment of the axes of the brush electrodes with the axis of the cylinder body 10 and anode 12. During disassembly, the cylinder head 46 and guide 48 may be withdrawn from the piston bore 14, during which time the key 66 is free to move in the groove 65 until it reaches an annular groove 65a defining a flange 67 at the end of the guide extending outwardly from its axis. When the annular groove 65a coincides with the position of the key 66, the guide may be rotated, relative to the piston 52, until it coincides with a small offset notch 68 in the flange 67, and then withdrawn from the piston.

To move the brush electrodes 34 into contact with the anode 12, pressure is applied to the cylinder head and piston assemblies 32 from the source 60, thus being applied to the pistons at chambers 52 and the ring faces 54. In response, the pistons move in the bores 14 and along the guides 48 until the applied pressure is balanced by the contact pressure of the graphite shoes 36 against the anode surface. A reduction in the air pressure in the manifold 58 results in a corresponding lessening of the contact pressure applied by the brush electrodes. The application of a vacuum to the manifold 58, of course, causes the brush electrodes to withdraw from the anode 12 in the opposite direction.

Returning to FIGURE 2, the assembly also includes a shield 68' for deflecting radiation at the arc away from the brush electrodes 34. The shield is spaced from the forward cooling manifold 26 by insulating spacers 70 to preclude striking of the arc to parts of the shield, and contains a circular cooling duct 72 which communicates with inlet and outlet conduits 74 and 76, similarly silver soldered to the shield plate. In general, the shield and forward and rear cooling manifolds 26, 16 are fabricated from materials which are highly heat conductive, while the invention is not limited to any particular materials, one brush electrode assembly which has proved satisfactorily utilizes brass for the cooling manifold 16, copper for the cooling manifolds 16, 26 and shield 68', and aluminum for the cylinder body. High brass has been found suitable.
for fabrication of the cylinder head 46 and piston 52, while precision ground stainless steel is preferred for the guide 48. As previously explained, a good brush electrode assembly must be capable of not only withstanding extremely high temperatures during operation, but must also apply a substantially constant total frictional pressure against the surface of the anode 12 as it is rotated and simultaneously advanced into the arc. That pressure must be maintained in the presence of appreciable deformities in the consumable electrode, as where the electrode is not consistently of circular cross-section.

In accordance with the invention, the use of a compressible fluid to activate the brush electrodes, in conjunction with the piston and cylinder head assemblies described, is effective to maintain a substantially constant pressure against the contacting surfaces of the brush electrode shoes against the anode surface. This is brought about by absorbing any pressure variations induced by movement of the brushes upon encountering a deformity of the consumable anode 12. To this end, the volume of the piston displacement is small in comparison with the total volume of the system, including the accumulator 62. Assuming, for example, an out-of-round condition of the anode 12 of about 1/16 inch, a corresponding movement of about 1/32 inch of opposed brushes and pistons 52 may result, or a total radial displacement of 1/16 inch. Assuming the cross-sectional area of the piston bore to be about .44 in.² (diameter = .750) the total volumetric change in the gas pressure system is about .055 l.(152.5 × .44) in.³. If all six pistons were to move simultaneously 1/32 inch, the total change in cubic displacement of the pressurized gas supply would be about .165 cubic inch. Any net decrease in cubic displacement tends to bring about an increase in pressure which is largely absorbed in the accumulator 52. For an accumulator of about two cubic feet capacity (5.256 cubic inches) a volume change in the system of .165 in.³ results in a pressure change of less than .005%. Preferably the accumulator volume exceeds the sum of the maximum displacement of the cylinders by a factor of at least 10,000.

While the requirements of any particular brush electrode assembly according to the invention will vary, depending on the particular application, the total contact area provided by the brushes against the anode surface in one assembly is about 18 in.² (3 in.² per brush), each brush exerting about 1 p.s.i. pressure against the anode surface for each 7 p.s.i. pressure applied to the gas supply manifold 58. During operation, sufficient coolant is supplied to the manifolds 16, 26 and radiation shield 68' to maintain the current carrying capacity in excess of 225 amperes per square inch of shoe contact pressure area. For the particular example given, the brush electrode assembly can adequately supply about 4,000 amperes to the anode. As earlier noted, the graphite brush shoes desirably have a high degree of compliance with the anode surface to present a substantially constant surface contact area and, therefore, a substantially constant pressure against the anode regardless of deformities in the concentricity of the anode rod.

Apparatus shown in the drawings can be used effectively and reliably in close proximity to the electrical arc at the end of the anode. It has been demonstrated, for example, that the electrode brush assembly can be positioned and operated in processes involving temperatures as high as 7,000°C, with the shield 68' located within two inches of the anodic terminus of the arc.

In summary, the present invention, utilizing a compressible fluid source in connection with an electrode brush actuating mechanism, is capable of supplying high load currents to a moving anode under extreme temperature conditions. It is, moreover, capable of maintaining a constant contact pressure against the anode, notwithstanding anode deformities resulting in radial displacement of the brush electrodes. Although the invention has been described with reference to a specific embodiment thereof, certain modifications and variations may readily occur to those skilled in the art. Accordingly, all such modifications and variations are intended to be included within the scope and spirit of the appended claims.

I claim:

1. An electrode brush assembly for supplying electrical current to a consumable electrode, comprising:
   a body providing a central aperture for receiving the consumable electrode and having therein a plurality of spaced cylinder bores extending generally radially thereto;
   a piston disposed in each of the cylinder bores for radial movement along the axis thereof;
   a brush electrode secured to each of the pistons and movable therewith to define a dimensionally variable central aperture for a consumable electrode through the body, each brush electrode providing a contact surface for electrically contacting a portion of the surface of the consumable electrode;
   means for cooling the body and each brush electrode with a circulating fluid coolant;
   means for connecting each brush electrode to a source of electrical current; and
   means for connecting to each of the pistons a source of compressible fluid to yieldably force the electrode surface into sliding contact with the surface of the consumable electrode, thereby to provide substantially constant-pressure electrical connections to the consumable electrode.

2. A brush assembly according to claim 1, further comprising:
   an accumulator means for connection between the compressible fluid source and the pistons for absorbing displacements of the compressible fluid by movement of the pistons within the cylinder bores.

3. A brush assembly as defined in claim 1, in which the cooling means includes:
   a manifold having inlet and outlet coolant passages therein and positioned in aligned, heat-transfer relation adjacent an end of the cylinder body.

4. A brush assembly as defined in claim 3, further comprising:
   a second manifold adjacent an opposite end of the cylinder body and having therethrough an internal passage for coolant.

5. A brush assembly as set forth in claim 3, in which the cooling means further comprises:
   conduit means connected to provide a flow path for the coolant from the inlet to outlet passages through each of the brush electrodes.

6. A brush assembly as defined in claim 5, in which:
   the conduit means are flexible.

7. A brush assembly according to claim 5, in which:
   the electrical power source is connected to the electrode brushes through the conduit means.

8. A brush assembly as defined in claim 1, further comprising:
   a radiation shield secured to the cylinder body to deflect radiation at the consumable end of the consumable electrode away from the cylinder body.

9. A brush assembly as set forth in claim 8, further comprising:
   means for internally cooling the radiation shield.

10. A brush assembly according to claim 8, in which:
   the radiation shield is electrically isolated from the cylinder body and brush electrodes.

11. A brush assembly as defined in claim 1, in which:
   each brush electrode is diametrically opposite another brush electrode, whereby diameter irregularities of the consumable electrode therebetween result in axial
movement in unison of the opposed pistons secured to each thereof.

12. A brush assembly in accordance with claim 1, in which the pistons have an interior axial recess extending thereinto and a ring-like head, the assembly further comprising:

a stationary piston guide of smaller diameter than and received in the axial recess of each piston and having therein a passage for supplying the compressible fluid to a chamber defined between the guide and the interior of the piston recess and to the head of the piston.

13. A brush assembly as defined in claim 12, further comprising:

means for preventing relative rotation between the piston and piston guide to maintain the brush electrodes aligned relative to the axis of the central aperture defined thereby.

14. A brush assembly as defined in claim 13, in which the guide includes an axial groove in the external surface thereof, the rotation preventing means comprising:

a key affixed to the piston and slidably extending into the groove.

15. A brush assembly as set forth in claim 14, in which:

the guide includes an annular groove defining a flange at the end thereof extending radially of the guide axis.

16. A brush assembly according to claim 15, in which:

the flange in the guide includes a notch displaced circumferentially from the axial groove to accommodate passage of the key therethrough upon moving the piston axially and rotating it in the bore upon physical coincidence of the key and the annular groove.

17. A brush assembly as set forth in claim 16, in which:

the sum of the cross-sectional areas of the piston recesses are substantially less than the sum of the contact surfaces of the brush electrodes.

18. A brush assembly according to claim 12, further comprising:

an accumulator connected intermediate the fluid source and the chambers, the volume of the accumulator being greater than ten times the sum of the volumes of the chambers.

19. A brush assembly according to claim 1, in which:

the brush electrodes are elongate in the direction of the axis of the cylinder body.

20. An electrode brush assembly for supplying electrical current to a consumable electrode, comprising:

an annular support member having a central aperture and a series of cylinder bores spaced about same and extending radially thereto;

a series of pistons disposed in the cylinder bores for radial movement therein;

a series of brush electrodes secured to and movable with the pistons radially towards the center of the aperture in the support member for engagement with a movable consumable electrode and providing a series of electrical contact areas therewith;

means for connecting a source of electrical current to the brush electrodes; and

a source of compressible fluid connected to force the brush electrode contact areas into sliding contact to the consumable electrode, thereby to provide substantially equalized frictional contact of the brush electrode areas against the surface of consumable electrode.

21. A brush electrode assembly as defined in claim 20, in which:

the compressible fluid is a gas, the assembly further comprising a manifold connected to the source and to each of the pistons, thereby to activate the pistons from a common fluid source upon connection of the manifold to the gas source.

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