May 7, 1968 R. A. MARSHALL 3,382,387

ELECTRIC CURRENT COLLECTION AND DELIVERY METHOD AND APPARATUS

Filed June 21, 1965

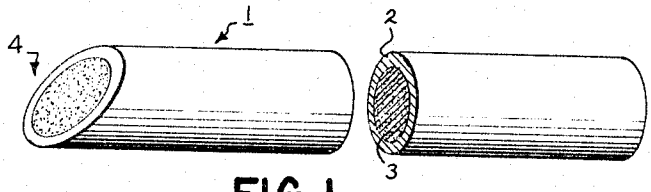


FIG. 1

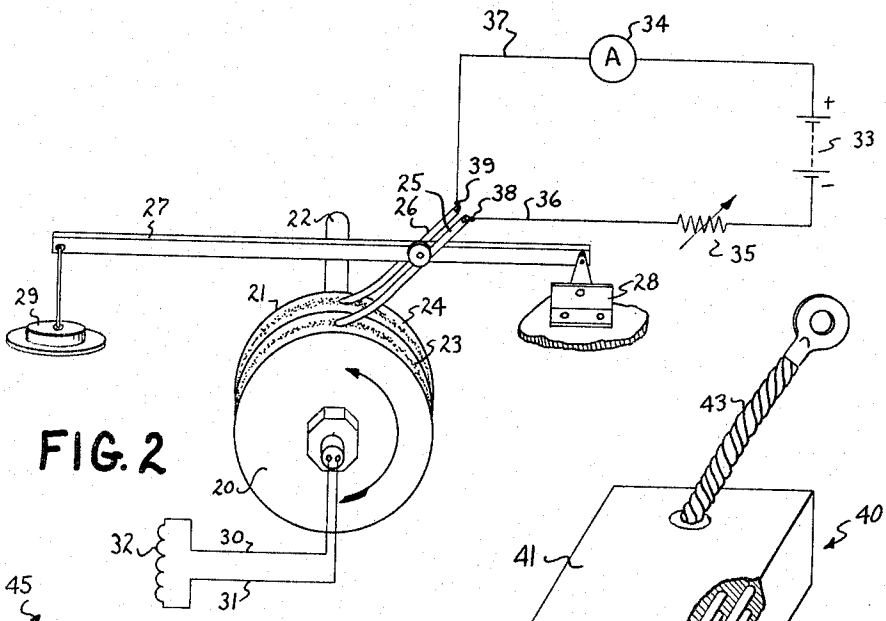


FIG. 2

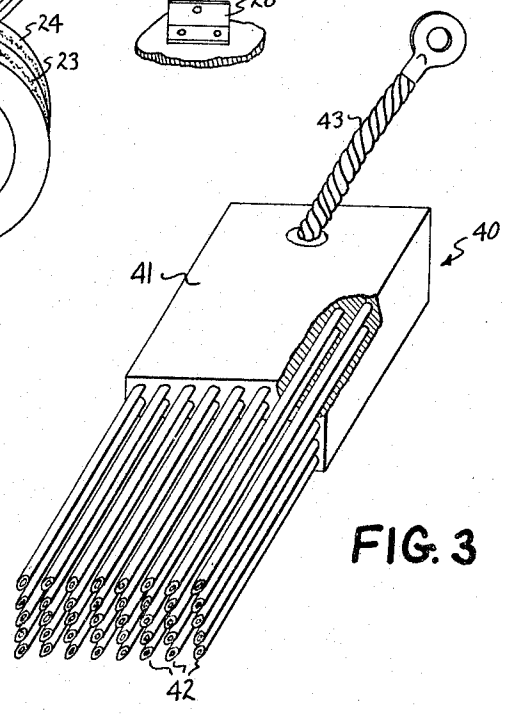


FIG. 3

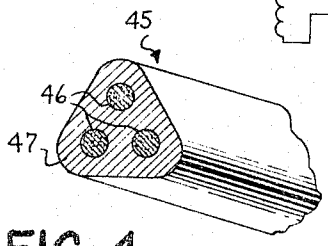


FIG. 4

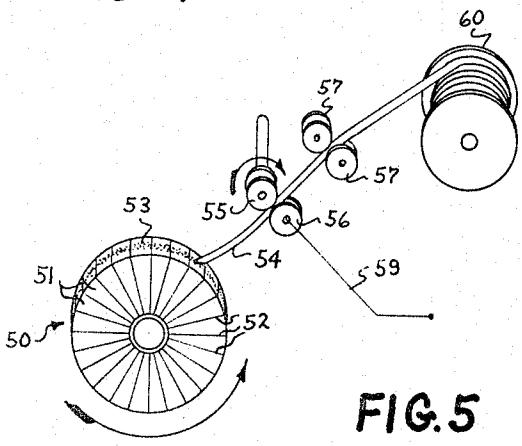


FIG. 5

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ELECTRICAL CURRENT COLLECTION AND DELIVERY METHOD AND APPARATUS

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ABSTRACT OF THE DISCLOSURE

A resilient wire of circular right cross section has a metal outer sheath enclosing a core of weld inhibiting material such as carbon. The resilient wire is used as a brush for making electrical contact to a sliding contact electric power transfer apparatus.

The present invention generally pertains to methods and apparatus for effecting a sliding electrical contact, and is more particularly concerned with the foregoing as applied to slip rings and commutators for electric motors, generators, instruments, and the like.

The normally stationary member used for sliding current transfer with a relatively movable conductive surface, as a slip ring, collector ring, or commutator, is known in the art as a "brush," and will be referred to as such herein. The term probably originated because of the marked resemblance of the bundles of flexible wire, early used for the purpose, to an ordinary household wire brush.

While the discovery of the carbon brush, and the many improvements made thereon, has essentially displaced the older bundles of wire from the marketplace, there has been little, if any, success since the advent of the carbon brush in substantially extending the maximum permissible continuous current density that can be transferred by brushes. Also, the maximum permissible continuous rubbing velocity, or relative motion between the brush and conductive surface, has not been increased appreciably heretofore. This is not to suggest important progress has not been made in both areas, but merely to point out the gains have been relatively small despite sustained effort over many years.

The present maximum continuous current density for electric brushes is in the order of 200 amperes per square inch, and more usually accepted as from 50 to 100 amperes per square inch for sustained operation. The prior solution to the problem of transferring large quantities of current has been to increase either the cross-sectional area or quantity of brushes used, or both. Such solution is obviously uneconomical and disadvantageous from most points of view.

The rubbing velocity of present brushes is ordinarily confined to less than approximately 6000 feet per minute. This problem has been met by decreasing the diameter of the slip rings in some applications. For a rotational velocity of 25,000 r.p.m., for example, the slip ring would be less than about 1 inch in diameter. Such small slip rings rapidly overheat due to the brush friction and ordinarily require extreme cooling techniques as submersion in a refrigerated dielectric liquid, to name but one apparent disadvantage.

Suffice it to say, when both high relative velocity and high current density problems are present in the same brush application, the situation is essentially unsolvable by heretofore known brush technology.

Accordingly, it is an object of my invention to provide an improved method and apparatus for transferring current by sliding electrical contacts.

Another object of my invention is to provide means for continuously transferring electric current by sliding

contact at relative velocities greater than heretofore possible.

Still another object of my invention is to provide means for continuously transferring electric current by sliding contact at current density greater than heretofore known.

Yet, another object of my invention is to provide means for continuously transferring electric current by sliding contact at greater velocity and at greater current density than heretofore possible.

Briefly, I have discovered that the current density and rubbing velocity limitations of prior art brushes are both overcome simultaneously by providing a brush having one or more resilient wires of highly conductive material, as copper or silver, for example, with a core of weld inhibiting material, or contaminant, as powdered natural graphite, for example. Each resilient wire is secured as a cantilever beam at one end and the opposite end is biased against the moving conductive surface to which sliding electrical contact is desired. In this way, I have achieved good sliding electrical contact at a velocity of 33,000 feet per minute with a current density of 5000 amperes per square inch of brush cross-sectional area, for continuously sustained operation and without special cooling techniques or the like.

While the specification concludes with claims particularly pointing out and distinctly claiming the subject matter of my invention, it is believed that the invention will be better understood from the following description taken in connection with the accompanying drawing wherein similar numerals designate corresponding components and in which:

FIGURE 1 illustrates a resilient wire suitable for use in accord with my invention;

FIGURE 2 is a schematic diagram of current transfer apparatus in accord with my invention;

FIGURE 3 shows a brush having a bundle of resilient wires of the kind illustrated in FIGURE 1;

FIGURE 4 is a right cross-sectional view of a resilient wire in accord with another embodiment of the invention; and,

FIGURE 5 is a schematic diagram of the present invention including an automatic resilient wire feed mechanism.

There is shown in FIGURE 1 a resilient wire **1** of circular right cross section that represents the presently preferred shape for use in my invention because axial symmetry facilitates fabrication, particularly in small diameter sizes, and provides uniform resilient bending characteristics independent of circumferential orientation. Resilient wire **1** comprises a metal outer sheath, or tube, **2** enclosing a core of weld inhibiting, or contaminant, material **3**. The end face **4**, of resilient wire **1**, is advantageously beveled, relative to the longitudinal axis of resilient wire **1**, in order to conform initially more closely with the moving surface to be contacted, when the wire is tilted at an angle to the surface, as is preferably the case.

Metal sheath **2** is fabricated of highly conductive metal. Copper and silver are presently preferred materials for sheath **2**, although other metals and alloys can, of course, be used. Weld inhibiting, or contaminant, material **3** is preferably powdered graphite that not only serves as a lubricant but also forms a conductive film that prevents actual physical contact, while preserving direct electrical contact, between sheath **2** and the metal of the moving surface. The presence of material **3** also advantageously serves to provide a contaminant, or impurity, between the adjacent metal surfaces that discourages formation of an alloy therebetween, i.e., material **3** is an "anti-flux." Thus, when materials other than graphite compositions are used in the present invention as weld inhibiting material **3**, the significant considerations include: (1) the extent to which friction heating is reduced, (2) the film-forming ability of the material, and (3) the effectiveness of the material as

an anti-flux. Some of the well-known lamellar metal compound lubricants, that have been used in carbon brushes, provide acceptable results, but I generally prefer graphite, particularly at the higher current densities to which this invention pertains.

A resilient wire, as shown in FIGURE 1, is advantageously fabricated by packing a metal tube with the weld inhibiting core material; plugging the ends of the tube and cold drawing down to the desired outer diameter. In one example, a copper tube 0.40 inch in outside diameter was filled with powdered natural graphite and plugged at one end with a pointed copper plug silver soldered in place and at the other end with a wooden plug. The copper plug end was led first through a plurality of tungsten carbide reducing dies of successively reduced diameter. The reduction in area was taken in steps of about 10 to 15 percent per die until the tube had become a resilient wire about the size of a paper clip wire (approximately 0.032 inch diameter). It is important that the initial metal thickness of the tube be greater than ordinary tube stock when resilient wires of less than about .060 inch outside diameter are to be fabricated in this way. The metal area is advantageously selected to be more than 40 percent of the total tube cross-sectional area, and, preferably, more than 50 percent thereof if wires less than about 0.032 inch outside diameter are to be drawn. Silver coated resilient wires of comparable size have been similarly fabricated by the foregoing process.

FIGURE 2 illustrates a sliding contact electric power transfer apparatus having two spaced discs **20** and **21** insulated from each other and mounted coaxially on rotatable shaft **22** for rotation therewith. The outer peripheral surfaces **23** and **24** of discs **20** and **21**, respectively, each provides a moving continuous track. Brushes comprising resilient wires **25** and **26** of the kind shown in FIGURE 1 are biased against surfaces **23** and **24**, respectively, by an insulating brush securing arm **27** having a pivot support **28** at one end and a weight **29** hanging from the opposite pivot end thereof. Discs **20** and **21** are fabricated of conductive material and electric power is transferred therethrough to conductors **30** and **31**, respectively, which are connected to a suitable rotatably mounted means as a motor or generator rotor winding, or an instrument, as a strain gauge, for example, all represented by resistance **32**.

Resilient wires **25** and **26** are conveniently mounted in holes or slots in arm **27** (not shown) so that they are essentially cantilevered and insulated from each other. For optimum performance, resilient wires **25** and **26** are adapted to trail at an angle of from 30 to 60 degrees to the plane of contact, although this is not essential to good performance.

The relatively stationary external apparatus includes a source of power, that can be a battery **33** as illustrated schematically, advantageously connected in series with a control means, as variable resistance **34**, and a convenient current measuring instrument **35**. Of course, battery **33** would be replaced ordinarily by suitable electric power utilization means in the case where resistance **32** represents an electric power generating means, as a generator armature winding, for example. The external apparatus is connected to resilient wires **25** and **26** by respective conductors **36** and **37** that are welded, brazed, or otherwise electrically attached thereto, as at **38** and **39**.

The material from which discs **20** and **21** are fabricated is advantageously selected to have a low affinity for the metal of sheath **2**. Thus, the two metals should be dissimilar and not readily alloyable. For example, the combination of copper discs with silver sheathed flexible wires has been found less advantageous at high rubbing velocities, whereas steel discs with either copper or silver sheathed flexible wires are the presently preferred embodiments of this invention.

While the apparatus of FIGURE 2 has been greatly simplified in the interest of more distinctly setting forth this invention, it will be appreciated by those skilled in the art that other equivalent structures will sometimes be more desirable. For example, the weight loaded brush holder shown is advantageously replaced by a spring-loaded brush holder in many applications. Also, the discs shown can be segmented commutators having substantially continues surfaces to be contacted when alternating current is to be simultaneously transferred and converted to unidirectional current.

Those skilled in the art can readily understand and practice my invention from the foregoing; however, the following specific examples are given in the interest of further appreciating the invention.

EXAMPLE 1

An apparatus similar to that shown in FIGURE 2 was constructed using a single rotatable disc of mild steel having an outside diameter of 4 inches. Current in the disc was conducted from a first continuous brush track on the peripheral surface of the disc to a second continuous brush track thereon spaced axially from the first track. Each of two brushes consisted of four resilient wires, of the kind illustrated in FIGURE 1, having parallel axes. The resilient wire outside diameter was 0.032 inch and the sheath was fabricated of fully work-hardened copper, as drawn. The core was powdered natural graphite and the core diameter was 0.020 inch. The disc was rotated about its central axis to provide a peripheral surface velocity of 15,000 feet per minute. The resilient wires were biased against the moving surface at a trailing angle of 45° and by a force perpendicular to the surface of 40 grams per wire. The cantilevered length of each resilient wire was 1 inch. The two brush tracks were axially spaced ½ inch and the individual resilient wires of each brush were relatively movable at the ends adjacent the disc. The individual wires of each brush ran on separate adjacent paths on the disc peripheral surface.

Electrical connection was made to each brush and an adjustable source of electric current having a difference of potential of about 20 volts D.-C. The current was adjusted to 20 amperes by a variable series resistance, or 5 amperes per flexible wire. The current density per wire was thus approximately 5000 amperes per square inch of flexible wire right cross-sectional area. Current transfer was observed to take place under these conditions for 30 minutes without overheating or sparking. The positive brush voltage drop was ½ volt and the negative brush voltage drop was 1 volt. The coefficient of friction was 0.3 for both brushes. The wear rate of the positive brush was 0.025 inch per hour while that of the negative brush was 0.010 inch per hour. The coefficient of friction was determined from measurements of the force required to restrain the brush arm in the plane tangent to the point of contact, or horizontal plane. The wear rates were determined by measurement of the downward mavement of the free end of the brush arm and the two voltage drops were charted on a graphical recorder having a time-sharing feature.

EXAMPLE 2

The same conditions and procedures of Example 1 were repeated, except that the disc was case-hardened mild steel. The results were essentially the same with a slight tendency for less disc wear and greater brush wear. The latter was increased approximately 5 percent.

EXAMPLE 3

The same conditions and procedures of Example 1 were repeated, except that silver, rather than copper, was used to fabricate the sheath of the resilient wires, and this particular run was continued for one hour. Again, no overheaing or sparking occurred. The wear rate of the positive brush was 0.045 inch per hour and that of the negative brush was 0.030 inch per hour. The coefficient of friction was 0.25 for both brushes. The voltage drop

at the positive brush was ½ volt and that at the negative brush was ¾ volt.

EXAMPLE 4

The same conditions and procedures of Example 1 were repeated except that the surface speed of the disc was 33,000 feet per minute and this particular run was contiued for forty-five minutes. There was no overheating or serious sparking and the sparking stopped altogether for fifteen seconds each time the disc tracks were touched lightly with a soft stone. The wear rate for the positive brush was 0.045 inch per hour and that for the negative brush was 0.010 inch per hour. The total voltage drop including both brushes was 2 volts.

EXAMPLE 5

The same conditions and procedures of Example 1 were repeated except that one brush only was changed to the silver sheath kind, the four resilient wires of each brush were arranged in tandem, and alternating current was applied to the brushes. The magnitude of current was adjusted to 5 amperes RMS per wire and the run was continued for one hour. Again, no overheating or sparking occurred. The wear rate for each silver sheathed wire was 0.035 inch per hour and that for each copper sheathed wire was 0.018 inch per hour. The coefficient of friction for the silver sheathed wire was 0.3 and that for the copper sheathed wire was 0.35. The voltage drops were 0.4 and 0.7 volt RMS for the silver and copper, respectively.

From the foregoing examples, perhaps the most startling result is the discovery that the resilient wire brush wear rate expressed in cubic inches of brush material expended per ampere hour of transferred current is within a factor of 2 of the available published data on ordinary metal-graphite brushes. This is true even though the rubbing velocity of the flexible wire in accord with my invention is increased by more than a factor of 2½ over prior art velocities, and in Example 4 the factor is more than 5.

FIGURE 3 illustrates a brush **40** having a body portion **41**, that is conveniently fabricated of copper, for example, with a plurality of resilient wires **42**, that can be of the kind described in conjunction with FIGURE 1, cantilevered therein. The wires **42** are preferably embedded in body **41** with their respective longitudinal axes parallel and the free ends thereof relatively movable. A suitable connector **43**, or "pigtail," is advantageously provided to facilitate electrical connection. The brush **40** can, of course, be otherwise shaped or adapted to accommodate any of the well-known brush holders used with slip rings and commutators.

FIGURE 4 illustrates a resilient wire **45** suitable for use in accord with this invention. Wire **45** includes a plurality of cores **46** and an enclosing sheath **47**, which are advantageously of the same materials as core **3** and sheath **2**, respectively, of FIGURE 1. Non-circular shapes for the resilient wire permit the wire to flex more readily in one direction than in another direction. The more flexible direction would most advantageously be selected to coincide with the plane of the brush track, in mose cases.

There is shown schematically in FIGURE 5 a commutator **50** having a plurality of conductive segments **51** separated by insulating spacers **52**, all as is well known in the art. Commutator **50** includes a substantially continuous conductive brush track **53** upon which a resilient wire **54**, of the kind described in connection with FIGURES 1 and 4, is continuously biased and resupplied by an automatic wire feed mechanism represented by driven pulley **55** and idler pulleys **56**, **57** and **58**. Electrical connection to wire **54** is effected through pulley **56** by a suitable conductor **59**, connected thereto. Resilient wire **54** is advantageously stored in a spool or coil **60**. Pulley **55** is conveniently driven by a gear reduction unit powered by the apparatus served, but can be otherwise energized as is well known.

There has been described herein an advantageous electrical brush that is capable of continuously transferring electrical energy at higher current densities, higher relative rubbing velocities, or both, than heretofore known brushes. In addition, the wear rate is commensurate with that already accepted in the art for less severe operating conditions. While the desired resilient, or springy, characteristic of the wire will vary from one dynamoelectric machine, or the like, application to another and will depend upon the materials used, I have found that the ratio of cantilevered length to over-all wire diameter should be greater than 10 for best performance, particularly with copper or silver as the sheath material and compacted graphitic material as the core. It appears that my invention provides a low effective mass, highly resilient, current collector capable of closely following unavoidable irregularities in a rapidly moving surface while retaining the desirable characteristics of anti-flux materials. Of course, the invention is in no way dependent upon the correctness of such attempted theoretical explanation.

While this invention has been described in connection with illustrative embodiments and specific examples, it is not limited thereto and various modifications will suggest themselves to those skilled in the art. For example, the resilient wire brush can take the form of gauze. It is therefore intended that the appended claims cover such modifications as do not depart from the direct spirit and scope of this invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In a sliding contact electric power transfer apparatus:
(a) a brush comprising a resilient wire having a conductive metal sheath and at least one core of weld inhibiting material;
(b) a conductive material, having a surface to be electrically contacted, movable relative to said wire; and,
(c) means for biasing said wire against said relatively movable conductive material so that said wire makes electrical contact with said surface and provides sufficient resiliency to accommodate irregularities in said surface.

2. The apparatus of claim **1** wherein said weld inhibiting material is at least in part graphitic.

3. The apparatus of claim **1** wherein the metal of said conductive metal sheath comprises a metal selected from the group consisting of copper and silver.

4. The apparatus of claim **3** wherein said relatively movable conductive material, having the surface to be contacted, is at least in part ferrous.

5. A dynamoelectric machine brush comprising a plurality of substantially parallel resilient wires cantilevered in a common support and each including a conductive metal sheath enclosing at least one core of compacted particulate weld inhibiting material.

6. The brush of claim **5** wherein the cantilevered length of each of said wires is more than ten times greater than the longest cross-sectional dimension thereof.

7. The brush of claim **5** wherein said sheath is copper and said weld inhibiting material is graphite.

8. In a dynamoelectric machine having a commutator:
(a) a brush comprising a resilient wire having a metal sheath enclosing at least one core of weld inhibiting material; and,
(b) means biasing said brush against said commutator so that one end of said wire makes resilient physical contact therewith.

9. The machine of claim **8** wherein said resilient wire is cantilevered and the length of the cantilevered wire is longer than ten times the longest cross-sectional dimension of said wire.

10. A sliding contact electrical power transfer apparatus comprising:

(a) a brush including a resilient wire having a conductive metal sheath and at least one core of compacted particulate material;

(b) a continuous track of conductive material movable relative to said wire; and,

(c) means for continuously biasing said wire against said track so that one end of the wire makes continuous sliding electrical contact with the track.

11. The apparatus of claim 10 wherein said compacted particulate material is comprised of graphite.

12. The apparatus of claim 10 wherein said conductive metal sheath is comprised of a metal selected from the group consisting of copper and silver, and the conductive material of said continuous track comprises ferrous metal.

13. The apparatus of claim 12 wherein said compacted particulate material is comprised of graphite.

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