June 7, 1960 G. A. FORSTER ET AL 2,939,977

ELECTRICAL BRUSH

Filed July 14, 1955

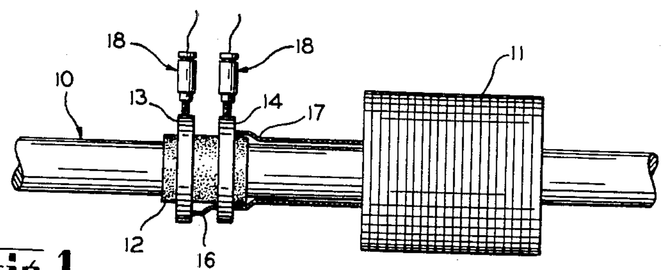

Fig. 1

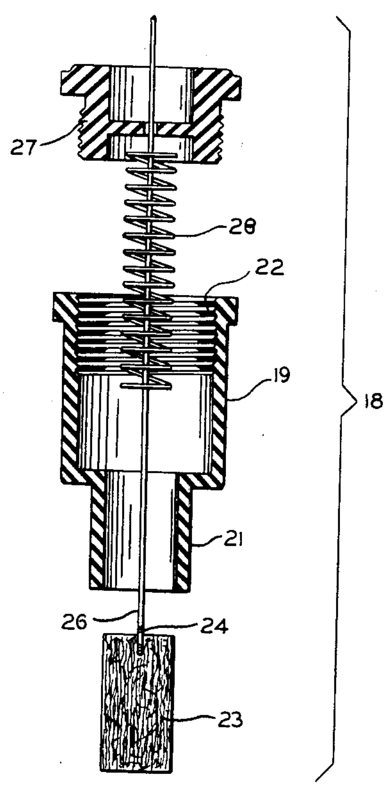

Fig. 2

INVENTORS
GEORGE A. FORSTER
CORD H. SUMP

BY Hill, Sherman, Meroni, Gross & Simpson
ATTORNEYS

nited States Patent Office

2,939,977

Patented June 7, 1960

2,939,977

ELECTRICAL BRUSH

George A. Forster, Westmont, and Cord H. Sump, Park Forest, Ill., assignors to Armour Research Foundation of Illinois Institute of Technology, Chicago, Ill., a corporation of Illinois

Filed July 14, 1955, Ser. No. 522,015

2 Claims. (Cl. 310—248)

The present invention is directed to improvements in electrical brush assemblies of the type employed in motors and generators to establish electrical contact with a rotating element.

The present invention has particular applicability to the field of electrical equipment intended for use in aircraft. One of the difficulties previously encountered in the design of motors and generators for aircraft use has been the tendency of brush assemblies to generate noise at their contact with slip rings or commutators. Since the generated noise extended over a wide band of frequencies, it frequently caused serious disturbances in electronic equipment, particularly radio, radar and the like.

A brush assembly to be useful in the types of electrical equipment mentioned must not only produce a minimum of noise but should still have a low contact resistance, a resistance to oxidation, and should be conformable to the surface of the rotating element which it engages. Furthermore, brushes of this type should provide a reasonable wear rate, i.e., they must be sufficiently tough to resist being ground down by friction between the brush and the slip rings or commutator.

Accordingly, an object of the present invention is to provide an improved electrical brush assembly in which the noise production is held to a minimum.

Another object of the invention is to provide improved electrical brush assemblies having long wearing characteristics, flexibility, and strength making them particularlya daptable for use in high speed motors and generators.

A still further object of the invention is to provide an improved electrical brush and slip ring combination having excellent electrical characteristics, and being relatively free of generated noise.

We have now found that particularly good electrical brushes can be made by matting and compacting together a plurality of discrete wires into a substantially coherent form. We particularly prefer to employ molybdenum wires because of their strength, toughness, and electrical properties. While molybdenum fiber brushes of this type result in a lower noise level with many different types of contacting surfaces, particularly good results are obtained when the molybdenum wire brushes are combined with a slip ring assembly or commutator assembly in which the surface which the fibers contact is composed of electrodeposited silver.

In order to achieve the maximum benefits of the invention, certain parameters in the design of the brushes should be observed. Probably the most important is the apparent density of the brush, the latter being a term which is defined as the ratio of the weight of a brush body of given dimensions to the weight of a block of solid molybdenum of the same dimensions. We have found that the brushes should have an apparent density between about 25% and 50% for best results. At densities substantially lower than 25%, the brushes tend to wear rapidly and in some cases to shred. At densities over 50%, the brushes tend to bounce i.e., fail to conform exactly with the surfaces of the slip rings, and cause high ring wear and in some instances seizure of the ring. It was also found that brushes having densities greater than about 50% produce larger variations in noise voltages.

The diameter of the individual wires making up the matted mass of the brush may vary, broadly, from about 0.001 to 0.010 inch, with a diameter in the range from 0.003 inch to 0.007 inch being preferred.

The brush assemblies can be manufactured in any of a variety of processes. The fibers can, for example, be hand laid in the desired orientation or they can be deposited on a foraminous screen or filter from suspension in a liquid medium. Whatever the means for laying the fibers, it is desirable to have the predominating fiber lay, i.e., the direction of the greatest number of fibers in compact, in line with the longitudinal axis of the compact.

The felted mass is then cold pressed to the desired density. Pressures of about 20,000 to 50,000 p.s.i., are typical for molybdenum with 30,000 p.s.i., being preferred. The pressure is applied in a direction perpendicular to the contact force when the material is used as a brush. The fibers need not be sintered, except where particularly strong compacts are required.

A further description of the invention will be made in conjunction with the attached sheet of drawings which illustrates a preferred embodiment thereof.

In the drawings:

Figure 1 is a somewhat schematic, fragmentary view with parts in elevation of a brush and slip ring assembly employing the principles of the present invention; and

Figure 2 is an enlarged, exploded view, partly in crosssection, illustrating a typical brush holder assembly of the type shown in Figure 1.

As shown in the drawings:

In Figure 1, reference numeral **10** indicates generally a shaft of an induction motor to which a rotor **11** is keyed, or otherwise secured. An insulating collar **12** is rigidly secured to the shaft **10**, the collar **12** serving to insulate a pair of slip rings **13** and **14** from the shaft **10** and from each other. A lead **16** connects the slip ring **13** to one end of the rotor windings, and a lead **17** connects the slip ring **14** to the other end of the windings.

The brush assemblies, illustrated generally at numeral **18** in Figure 1 are best illustrated in the exploded view of Figure 2. As seen in that view, the brush assemblies **18** may include a hollow cylindrical brush holder **19** of insulating material having a reduced diameter base portion **21** and an internally threaded upper end portion **22**.

The brush element proper consists of a compacted mass **23** of molybdenum fibers, preferably oriented so that the predominating direction of fiber orientation is lengthwise of the brush. A ferrule **24** is rigidly connected to the matted mass **23** and serves to anchor a lead-in wire **26**.

One end of the matted body **23** is tightly received within the reduced diameter base portion **21** of the brush holder **19**, with a sufficient amount of the matted mass **23** protruding beyond the end of the reduced diameter portion **21** to be pressed into conforming relation with the surfaces of the slip rings **13** or **14**. A helical spring **26** received within the holder **19** urges the brush assembly outwardly into good running contact with the surfaces of the slip rings. The top end of the spring **26** is bottomed against a cap **27** which is received in threaded engagement within the threaded portion **22** of the holder **19**.

Numerous experimental tests, both under ordinary conditions and under conditions simulating high altitude flight have shown that the brush assemblies of the present invention have excellent wear properties and provide only a very low level of noise output. In making the noise level tests, a high input impedance vacuum tube volt meter was connected across the slip ring brush assembly, and a cathode ray oscilloscope was connected in parallel with the volt meter to observe the type of noise voltage being generated. Measurements of noise voltage and brush wear were made only after allowing a certain amount of "run-in" time for each brush tested. The amount of "run-in" time necessary was considered to be the time required for the noise voltage to reach a stable point. The brush wear rate was determined by accurately weighing the brushes by means of a pan balance before and after running the brush for one hour. The difference in the two weights was taken as the amount of wear and the percentage change per hour was then calculated. A brush pressure of 5 lbs. per square inch was used for all measurements.

The following table illustrates the results obtained at various brush densities, fiber diameters, slip ring speeds, and brush currents;

NOISE VOLTAGE AND WEAR-RATE

Molybdenum-wool brushes on electrodeposited silver and brass

Brush Parameters		Ring Speed, Feet Per Minute	Brush Current, Milliamperes D.C.	R.M.S. Noise Voltage, Millivolts	Wear Rate, Percent Per Hour	Ring Material
Apparent Density, Percent	Fiber Diameter, Inches					
25	0.005	10,000	100	0.15	1.13	Silver.
35	0.005	10,000	100	0.14	0.51	Do.
55	0.005	10,000	100	0.8	0.96	Do.
25	0.005	10,000	1,000	1.1	1.22	Do.
35	0.005	10,000	1,000	1.7	0.88	Do.
55	0.005	10,000	1,000	8.0	0.28	Do.
35	0.0015	20,000	100	0.3	0.14	Brass.
35	.003 to .007	20,000	100	5.0	0.35	Do.
35	0.005	20,000	100	10.0	0.65	Do.
35	0.0015	20,000	500	1.3	0.31	Do.
35	.003 to .007	20,000	500	25	0.32	Do.
35	0.005	20,000	500	300	0.70	Do.
25	0.0015	20,000	100	0.32	0.48	Do.
35	0.0015	20,000	100	0.28	0.21	Do.
50	0.0015	20,000	100	0.28	0.41	Do.

The wires employed in manufacturing the brushes employed in the tests described above had an average length of about 0.5 inch. Succeeding tests indicated that longer fibers, specifically those having an average length of about 1.5 inches gave lower noise voltages, all other conditions being equal. Accordingly, we prefer to employ fiber lengths at least 0.25 inch in length and preferably at about 1.5 inches. The following illustrates the effect of changing the fiber length upon the noise voltage generated, and the wear rate observed.

CHARACTERISTICS OF BRUSHES OF 35% DENSITY, 0.0035 INCH WIRE SIZE

Fiber Length, Inches	Brush Size, Inches	R.M.S. Noise Voltage, Millivolts	Wear-Rate, Percent Per Hour
0.5	0.25 x 0.25	1.3	
0.5	0.25 x 0.25	1.2	1.3
1.5	0.25 x 0.25	0.3	
1.5	0.25 x 0.25	0.35	0.94
0.5	0.25 x 0.5	0.6	
0.5	0.25 x 0.5	0.45	0.78
1.5	0.25 x 0.5	0.25	
1.5	0.25 x 0.5	0.22	0.70

Additional tests were made with brush currents up to one ampere and peripheral ring speeds of 30,000 feet per minute. The noise voltage was found to be proportional to increases in brush current and ring speed. The wear rate of the brushes was proportional to the ring speed but apparently was not significantly effected by increased brush currents. A typical value of noise voltage obtained by operating a brush on a bras ring at 30,000 feet per minute with a brush current of 100 milliamperes D.C. is 0.58 millivolt, as compared to 0.18 millivolt for the same brush running at 10,000 feet per minute. The

rate of increase of noise voltage with increase of speed is much less apparent where silver coated slip rings are employed.

In connection with the selection of slip ring materials, it was previously noted that electrodeposited silver forms the best commutating surface for the molybdenum fiber brush. Other metals, however, can be employed but at a sacrifice in noise level. For instance, the noise voltages observed when brass slip rings were employed were roughly twice these obtained with silver. Rhodium slip rings exhibited noise factors of about 2 to 3 times that obtained for silver. Rings made of coin silver (90% silver 10% copper) exhibited noise voltages not substantially higher than for pure silver, but exhibited greater brush and ring wear than pure silver. Slip rings made of stainless steel gave rather high noise voltages and caused considerable heating of the brushes at high speeds.

It appears that the best slip ring materials are those metals or alloys such as silver or brass which exhibit substantially no mutual solubility with molybdenum. Consequently, these combinations lack the tendency to alloy, weld, or gall at the contact surfaces. The rather poor results obtained with stainless steel slip ring materials bears out this requirement, because stainless steel and molybdenum are capable of substantial alloying.

The brushes of the present invention also exhibited excellent characteristics at simulated high altitude conditions. When tested at conditions of 8.5 inches mercury pressure and a temperature of minus 59° F., corresponding to conditions at an altitude of approximately 30,000 feet, there was little change noted from the values obtained for room temperature and sea level pressures. Noise voltages and wear rates were either unchanged or in some cases reduced. At these conditions, the typical values obtained for a brush current of 100 milliamperes D.C. at a speed of 20,000 feet per minute were as follows; for electrodeposited silver, a noise voltage of 0.18 millivolt with a brush wear rate of 0.14%; for the brass slip rings, a noise voltage of 0.26 millivolt and a wear brush rate of 0.6%.

The frictional characteristics of various ring materials were also tested. This test was made by measuring the power input to the drive motors, the power required to rotate the slip ring at a constant speed being recorded with and without brush loading. The difference between these two values was taken as an indication of the power loss due to friction. Such measurements show that electrodeposited silver had the lowest loss due to friction and that brass was slightly higher. Stainless steel had a much higher loss due to friction than either brass or silver.

From the foregoing it will be apparent that the brush assemblies of the present invention provide long wearing, tough brush elements generating only a minimum amount of noise when in use.

It will be understood that modifications and variations may be effected without departing from the scope of the novel concepts of the present invention.

We claim as our invention:

1. An electrical brush comprising a matted mass of molybdenum wires, said mass having an apparent density of from 25 to 50% of the theoretical density of molybdenum and said wires having diameters in the range from 0.001 to 0.010 inch.

2. An electrical brush comprising a mass of molybdenum wires matted together into an elongated brush assembly wherein the predominating direction of the fiber lay occurs lengthwise of said brush, said mass having an apparent density in the range from 25 to 50% of the theoretical density of molybdenum, and said wires having diameters in the range from 0.001 to 0.010 inch.

References Cited in the file of this patent

UNITED STATES PATENTS

556,176	Chaplin	Mar. 10, 1896
589,162	Chaplin	Aug. 31, 1897
1,002,648	Corey	Sept. 5, 1911
1,396,948	Cooley	Nov. 15, 1921
1,494,927	Merrill	May 20, 1924
2,449,078	Lindenblad	Sept. 14, 1948
2,696,570	Pandapas	Dec. 7, 1954

FOREIGN PATENTS

27,621	Great Britain	of 1911

OTHER REFERENCES

"Electrical Contacts," by Fansteel Metallurgical Corp., N. Chicago, Ill., page 8.