

[54] **METHOD FOR MAKING
ARMATURE-COMMUTATOR ASSEMBLY
HAVING ARMATURE WINDING OF VERY
SMALL DIAMETER**

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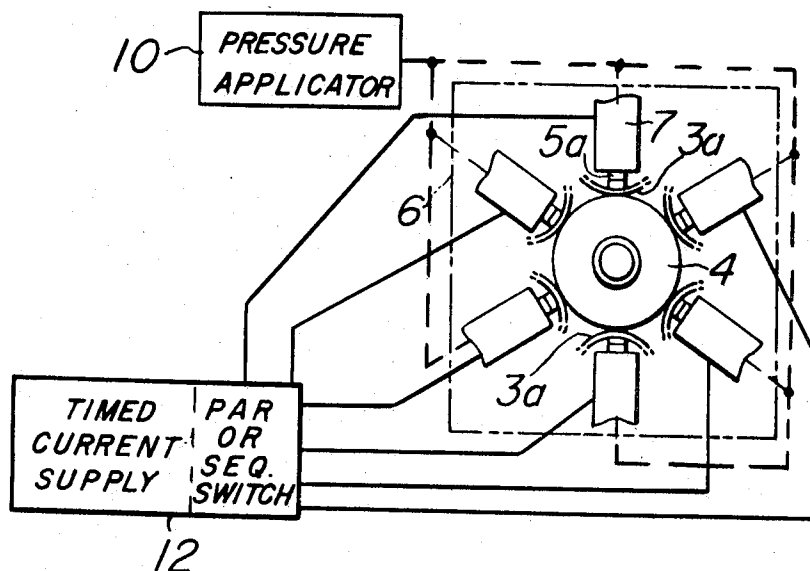
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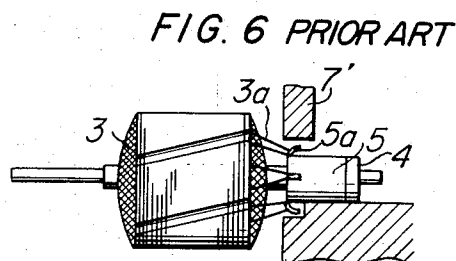
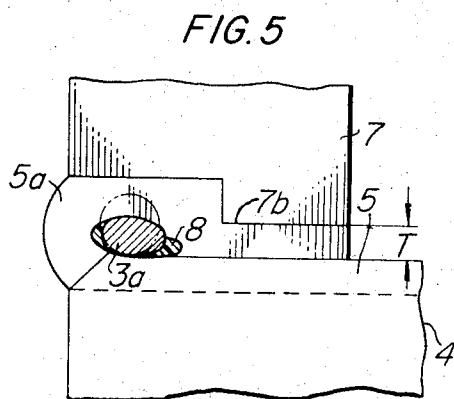
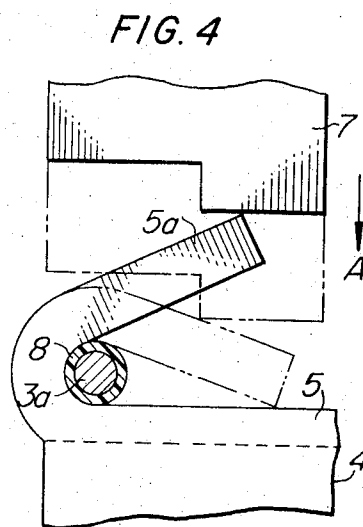
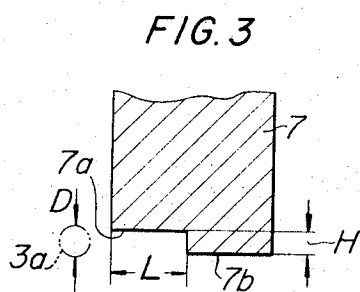
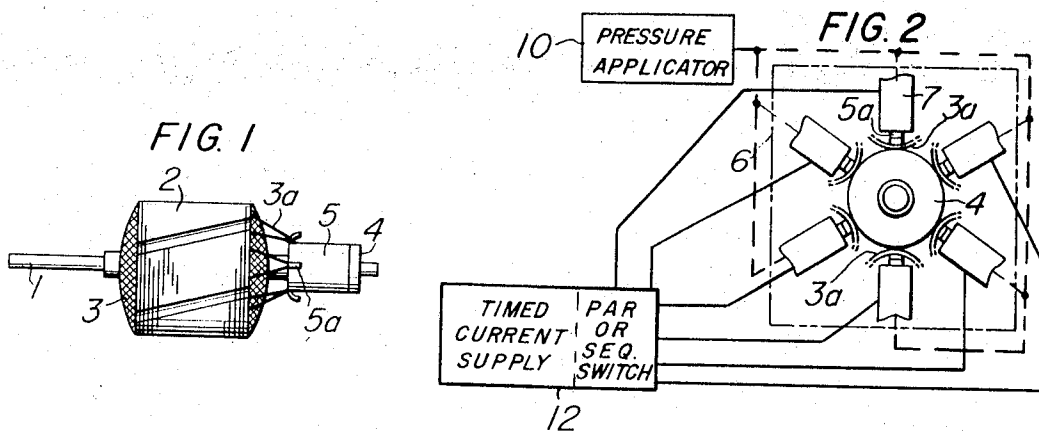
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[57] ABSTRACT

Apparatus and method for making an armature-commutator assembly having an armature winding wire of very small diameter comprising forming a plurality of wire-engaging fingers on the commutator, engaging a plurality of insulated conductors led out of the armature winding with the fingers, applying equal pressure simultaneously to all the engaging portions by a plurality of electrode bars whose number is equal to the number of the fingers and which have at their engaging end a recess portion of a depth which is approximately equal to the diameter of the conductor, and while continuing to apply that pressure, supplying to the electrode bars either equal valued currents simultaneously, or successively reduced currents sequentially for electrically connecting the fingers with the conductors.

15 Claims, 6 Drawing Figures





METHOD FOR MAKING ARMATURE-COMMUTATOR ASSEMBLY HAVING ARMATURE WINDING OF VERY SMALL DIAMETER

This application is a continuation-in-part of our co-pending application, Ser. No. 810,238, filed Mar. 25, 1969, now abandoned.

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

This invention relates to apparatus and methods for making an armature which is integrally connected with a commutator and has an armature winding wire of very small diameter, and more particularly to improvements in the apparatus and method of joining the armature winding to the commutator for providing electrical connection therebetween.

2. DESCRIPTION OF THE PRIOR ART

Heretofore, various methods have been proposed to provide an electrical connection between an armature winding and a commutator for making an armature-commutator assembly. Of these methods, the soldering method is generally preferred since it ensures a positive electrical connection. Recently, a method of joining called fusing has been developed which includes forming a wire-engaging finger projecting from a commutator, bending the finger in the form of a hook, engaging an insulated-conductor of an armature winding with the finger, engaging an electrode bar with the finger from above to apply pressure thereto, supplying a current of suitable magnitude to the electrode bar for a suitable time under the above state thereby to thermally destroy the insulation covering existing on the conductor and to expose the core conductor, and deforming the finger so that a sufficient electrical contact can be maintained between the finger and the conductor. Although this method of joining is defective with respect to the reliability of the electrical connection compared with the soldering method described above, it has great advantages in that a high working speed can be attained with high efficiency and the work can be automated. Therefore, a further development in this technique is expected. As a small-sized, light-weight and high-speed armature is increasingly demanded, the fusing method must necessarily be employed when A I E E (American Institute of Electrical Engineers) Class H or Class C heat-resisting wires are used to form the armature winding. This is because the insulation covering of these wires can not completely be peeled off with mere immersion in a solder bath or in a bath of a conventional covering peel-off agent, and as a result, a complete electrical connection can not be obtained.

However, the fusing method described above has been defective in that the quality of produced armatures fluctuates widely due to a lack of precise control of the manufacturing process. Thus, various problems including a lack of reliability of the electrical connection, lack of strength of the wire after fusing, and non-uniformity of the quality have arisen when an armature winding formed from a wire of very small diameter of, for example, less than 0.3 mm is electrically connected with a commutator. In order to have a secure electrical connection, the following conditions are requested:

1. The insulation covering should securely be thermally decomposed and peeled off so that the clean copper surface of the core conductor can be exposed.

2. The covering material thus decomposed and peeled off should flow out of the interface between the copper forming the finger and the exposed copper surface of the core conductor so that an intimate contact can be established therebetween.

3. No gap should exist between the copper forming the finger and the copper surface of the core conductor so that the contact portion can safely be protected against oxidization, sulfurization or any other corrosion which gives rise to unstable flow of electricity as time elapse. In order to satisfy these conditions, the magnitude of current supplied, duration of conducting the current and pressure applied in the connecting operation must properly be selected.

However, according to the prior art fusing method described above, conductor wires 3a led out of an armature winding 3 are engaged with corresponding fingers 5a provided on a commutator 4 as shown in FIG. 6 and then these engaging portions are compressed by a flat electrode bar 7' one after another for the connecting operation by supply of current therethrough. Thus, even when the individual engaging portions are supplied with current of the same magnitude and applied with pressure of the same degree, the above conditions can not be utterly satisfied. As a result of our investigation of the above problems, we found that a gradual temperature rise took place in the commutator segments after the current was first supplied. We concluded that the non-uniform finish results from the fact that the resistance to plastic deformation of copper varies with the rise in temperature during the above period. Such a phenomenon is not so marked when a wire having a relatively large diameter of more than 0.3 mm is employed and a fluctuation in quality is allowable. However, a serious problem arises from the above phenomenon when a wire having a small diameter of less than 0.3 mm is employed, such that even though both the currents and pressures applied to the electrodes are the same, the section of the conductors might be reduced excessively and the insulation covering the conductors might fail in thermal-decomposition due to variation of the resistivity to plastic deformation of the conductors.

SUMMARY OF THE INVENTION

It is therefore a primary object of the present invention to provide a method of making an armature-commutator assembly having an armature winding of very small diameter wire which assembly is formed by fitting an iron core having an armature winding of very small diameter wire wound therearound and a commutator on an armature shaft and then providing electrical connection between said armature winding and said commutator, said method comprising the steps of forming a plurality of wire-engaging fingers on said commutator, engaging a plurality of insulated conductors led out of said armature winding with said fingers, applying pressure simultaneously to all the engaging portions by a plurality of electrode bars whose number is equal to the number of said fingers and which have at their engaging end a recess portion of a depth which is approximately equal to the diameter of said conductor, and supplying currents of the same value to said electrode bars simultaneously or supplying controlled currents successively for electrically connecting said fingers with said conductors while maintaining said applied pressure.

Another object of the present invention is to provide a method of making an armature-commutator assembly as above-mentioned in which the electrode bars have a recess length which is smaller than the length of said fingers.

Another object of the present invention is to provide a method of making an armature-commutator assembly having an armature winding of very small diameter in which a further step of pre-forming a thin film of low-melting metal on the surface of said wire-engaging fingers provided on said commutator is added to the first method described above so as to ensure a positive electrical connection between said fingers and said conductors.

According to the present invention, individual engaging portions can be placed under the same joining conditions and the flow of the insulating covering as well as the exposure of the core conductor can be promoted without reducing the strength of the conductor. As a result, an electrical connection structure of high quality can be provided between the armature winding and the commutator.

According to the present invention, further, the exposed surface of the conductor and the surface of the finger can be brought completely into intimate contact with each other at their joining portions so as to obtain an electrical connection structure of high quality which is safe against oxidization, sulfurization and other corrosion which give rise to an unstable flow of current through the connection with a lapse of time.

The above and other objects, features and advantages of the present invention will be apparent from the following description when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a front elevational view of an armature-commutator assembly made by the method of the present invention.

FIG. 2 is a side elevational view showing the joining process for providing an electrical connection between the armature winding and the commutator.

FIG. 3 is an enlarged sectional view showing the contour of the working end of an electrode bar used in the joining process described above.

FIGS. 4 and 5 are enlarged schematic views showing the detail of the joining process.

FIG. 6 is a partly sectional, front elevational view showing the joining process in the prior art method.

Throughout FIGS. 1 to 6, like reference numerals are used to denote like parts.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, there is shown an armature-commutator assembly made in accordance with the method of the present invention. An iron core 2 having an armature winding 3 of insulated wire of very small diameter of less than 0.3 mm wound therearound is mounted on an armature shaft 1 in coaxial relation with a commutator 4. Wire-engaging fingers 5a extend from commutator segments 5 of the commutator 4, and conductors 3a led out of the armature winding 3 engage the corresponding fingers 5a to establish an electrical connection between the armature winding 3 and the commutator 4.

In the manufacture of the armature-commutator assembly described above, the armature winding 3 is wound around the iron core 2 according to a known method and the iron core 2 and the commutator 4 are fitted on and fixed to the armature shaft 1. Then, the conductors 3a led out of the armature winding 3 are engaged with the wire-engaging fingers 5a provided on the commutator 4 and the fingers 5a are bent to hold therein the conductors 3a. The commutator portion is then placed in a joining device 6 as shown in FIG. 2. Although not shown in detail, the joining device 6 comprises a plurality of electrode bars 7 whose number is equal to the number of the fingers 5a, pressure applying means 10 such as cylinders or cams for simultaneously moving the electrode bars 7 toward and away from the fingers 5a, and a timed power source 12 for supplying controlled currents to these electrode bars 7 either in parallel with the same value (amplitude) or sequentially with successively less values, as later explained, to overcome the prior art non-uniform heating problem. To prevent the applied pressure from reducing the cross-section of the metal of conductor 3a excessively, each electrode bar 7 is provided at its working end with a recess 7a and a land 7b, and the depth H of the recess 7a as measured from the surface of the land 7b is approximately equal to the diameter D of the conductor 3a. $H = D - (0.02 \text{ mm to } 0.05 \text{ mm})$ is preferred. The length L of the recess 7a is smaller than the length of the finger 5a.

The electrode bars 7 are simultaneously urged by pressure applicator 10 toward the fingers 5a. Thus, because of such simultaneous urging, each electrode bar 7 engages a respective finger 5a at a position as shown by the solid lines in FIG. 4 and successively compresses that finger 5a until the tip of the finger 5a abuts the outer peripheral surface of the commutator 4 as shown by the broken lines. Such simultaneous pressing on the fingers prevents any tilt of the commutator and is continued while current of a suitable magnitude is supplied to the electrode bars 7 simultaneously or sequentially as below explained and at either the solid line or dotted line position of FIG. 4. The pressure and temperature rise caused by the current deforms the respective finger 5a into the form shown in FIG. 5. It will thus be appreciated that the tip of the finger 5a is deformed by the application of current and pressure caused by the electrode moving closer to the commutator so that the engaging portions between the fingers 5a and the conductors 3a are securely placed under the same joining conditions. Immediately before the state shown in FIG. 5 is reached, the insulation covering 8 existing on the surface of the conductor 3a is completely thermally destroyed. In order to cause lateral flow of the destroyed insulation covering material so as to preclude the presence of the covering material in the interface of the core conductor and the finger 5a joined together, the pressure applied to the conductor by the electrode must be large enough to make the tip of the finger deformed, but not so large as to excessively reduce the sectional shape of the conductor which results in a reduction in strength of the conductor at the connection. In order to satisfy the above requirement, the electrode bar 7 is provided with the recess 7a whose depth is approximately equal to the diameter of the conductor. Thus, in the final stage of compression shown in FIG. 5, the land 7b of the electrode bar 7 is spaced a predetermined distance T (which is approximately equal to

the thickness of the finger 5a) from the outer peripheral surface of the commutator 4, and the conductor 3a is not so flattened. In the course of crushing the conductor 3a, the thermally destroyed and peeled-off insulation covering 8 flows laterally out of the interface between the conductor 3a and the finger 5a. Therefore, the core conductor is completely exposed and its surface is brought into intimate contact with the surface of the finger 5a. The tip portion of the finger 5a is compressed by the land 7b of the electrode bar 7 and is joined intimately to the commutator segment 5 to enclose the conductor 3a as seen in FIG. 5. Thus, an electrical connection of high quality can be obtained and an armature-commutator assembly as shown in FIG. 1 is completed.

For securing the fingers to the conductors in one embodiment, currents of the same value are supplied by the timed current supply 12 to all the engaged portions in parallel, i.e., simultaneously so as to control the temperature rise thereof substantially to the same degree. Alternatively, the controlled currents may be supplied from source 12 sequentially, in which case control means therein determine the order of current supply to the electrode bars 7 and supply a smaller current to the succeeding electrode bar 7 than the current supplied to the preceding electrode bar 7 so that controlled currents of successively reduced values are supplied to the respective electrode bars 7 starting from the first electrode bar in the state in which all the fingers 5a are compressed by the corresponding electrode bars 7. Of course, in the above embodiments during all the time that currents are applied to the electrode 7, either simultaneously or sequentially, all the electrodes remain under substantially equal pressures as effected by applicator 12. It is to be understood that if it were not for the fact that currents of the same value are applied simultaneously, or currents of successively less values are applied sequentially, the positions of the electrodes would not all be the same with respect to their fingers 5a as shown in FIG. 5. However, this drawback of the prior art is overcome by this invention.

With respect to values of the applied pressure and currents, it should be noted that these generally depend upon the size of the commutator, especially length and thickness of the finger, and type and thickness of the windings.

For example, the following values are exemplary for commutators and windings in which the commutator is 8 mm diameter, 11 mm long with fingers that initially are spread to an overall diameter of 14 mm and are 1 mm thick and 5 mm long, while the winding has a copper wire diameter of 0.22 mm and two 8 micron thicknesses of insulation, the inner one being a polyester resin (polycarboxylic isocyanate) and the outer layer a polyamide resin:

- Pressure simultaneously applied — 25 kg/each electrode.
- When the currents are simultaneously applied.
Currents: 170~1800 ampere/each electrode
Timed: 11 cycle (Power cycle 60 c/s)
Applied Pressure: 25 kg/electrode
- When the currents are sequentially applied

Electrode No.	Current (Ampere)	Time (Cycle)*	Pressure kg/electrode
1	1750 ~ 1800	11	25
2	1700 ~ 1750	11	25
3	1650 ~ 1680	11	25
4	1620 ~ 1650	11	25

*Employed power cycle 60 cycle/sec

When the currents are sequentially supplied, it may be possible to control the pressure or time sequentially in addition to, or in place of, the sequential control of the currents. However, since the necessary heat quantity for fusing is represented by I^2RT , the current control is most effective for controlling the fusing. For this purpose, a plurality of transformers are prepared for the respective fusing commutators and the current supplied to the electrode is controlled by changing phase angle of a current supplied to the transformer connected thereto.

In order that the electrical connection can be made more stable against oxidization, sulfurization and other corrosion, the joining surfaces of the finger 5a and the conductor 3a must contact each other completely. The above purpose can not be attained by a method of supplying a large current to the electrode bar 7 to expect fusing between the finger 5a and the conductor 3a due to partial fusion of the conductor 3a, since the conductor 3a has a very small diameter and would be completely melted by such a large current. Therefore, other methods must necessarily be resorted to. According to the most preferable method, a low-melting metal such as tin, cadmium, zinc or lead or an alloy of some of these metals may be employed so that the metal or alloy is easily fused by the heat generated as a result of current supply, and when cooled to solidify, the metal or alloy provides a firm bond between the joining surfaces of the finger 5a and the conductor 3a. Such metal or alloy may preliminarily be coated in a thin layer on the surface of the wire-engaging finger 5a, and the first invention described above may be performed to attain the desired purpose.

We claim:

1. A method of making an armature-commutator assembly having an armature winding of insulated wire of very small diameter which assembly is formed by fitting an iron core having an armature winding of said very small diameter wire wound therearound and a commutator on an armature shaft and then providing electrical connection between said armature winding and said commutator, said method comprising the steps of
 - a) forming a plurality of wire-engaging fingers on said commutator,
 - b) engaging a plurality of insulated wire conductors led out of said armature winding with engaging portions of said fingers,
 - c) deforming the engaged conductors by applying substantially equal pressure simultaneously to all the engaging portions by a plurality of electrode bars whose number is equal to the number of said fingers, and which have at their engaging end a recess portion of a depth which is approximately equal to the diameter of said conductor, wherein each said recess portion is superposed over a respective one of said conductors and by virtue of the recess portions controlled deformation of said conductors occurs, and
 - d) supplying a substantially uniformly commutator heating controlled current to said electrode bars for electrically connecting said fingers with said conductors.
2. A method according to claim 1, which comprises a further step of pre-forming a low-melting metal film on the surface of said wire-engaging fingers provided

on said commutator so as to ensure a positive electrical connection between said fingers and said conductors.

3. A method of making an armature-commutator assembly comprising the steps of:

forming a plurality of conductor-engaging fingers on said commutator,

engaging a plurality of insulated conductors led out of an armature winding with engaging portions of said fingers formed by bending end portions of said fingers over the commutator,

applying pressure to said engaging portions simultaneously by electrode bars corresponding thereto, and

supplying successively decreasing controlled currents to said electrode bars sequentially, while maintaining said applied pressure.

4. A method according to claim 3, including limiting said pressure as it is effectively applied to the respective conductors engaged by said fingers by using said electrode bars formed at their finger engaging end with a recess superposing the conductor and having a depth approximately equal to the diameter of said conductor and having a length smaller than the length of said fingers.

5. A method according to claim 3, wherein the surfaces of said fingers are coated with a low-melting metal prior to engaging said fingers with said conductors.

6. A method of making an armature-commutator assembly comprising the steps of:

forming a plurality of conductor-engaging fingers on said commutator,

engaging a plurality of insulated conductors led out of an armature winding with engaging portions of said fingers formed by bending end portions of said fingers over the commutator,

applying pressure to said engaging portions simultaneously by electrode bars corresponding thereto wherein said pressure is limited as it is effectively applied to the respective conductors engaged by said engaging portions of said fingers by using said electrode bars formed at their finger engaging end with a recess, each of which superposes a respective conductor and has a depth approximately equal to the diameter of said conductors and has a length smaller than the length of said fingers whereby deformation of the conductors is controlled, and

supplying said electrode bars simultaneously with currents of the same value, while maintaining said applied pressure.

7. A method of making an armature-commutator assembly according to claim 6, wherein the surfaces of said fingers are coated with a low-melting metal prior to engaging said fingers with said conductors.

8. A method of making an armature-commutator assembly having an armature winding of insulated wire of very small diameter, comprising the steps of:

forming a plurality of conductor-engaging fingers on said commutator,

coating the surfaces of said fingers with tin,

engaging a plurality of insulated conductors led out of said armature winding with engaging portions of said fingers formed by bending end portions of said fingers over the commutator,

applying equal pressure simultaneously to all the engaging portions by electrode bars respectively corresponding thereto to deform said conductors,

limiting the applied pressure as it is effectively applied to said conductors by using said electrode bars formed at the engaging end thereof with a recess superposing said conductor and having a depth approximately equal to the diameter of said conductor whereby deformation of said conductors is controlled, and

concurrently supplying equal valued currents to said electrode bars simultaneously for fusing said fingers with said conductors.

9. A method of making an armature-commutator assembly comprising the steps of:

connecting a plurality of insulated conductors extending from an armature winding to a respective plurality of projecting commutator fingers having portions bent over the conductors and commutator to hold the conductors between the respective fingers and commutator, and

fusion welding said fingers and conductors by simultaneously pressing each of said fingers onto its insulated conductor and against said commutator with controlled limited conductor deformation and concurrently passing current through each pressed finger and the commutator, wherein said finger pressing is effected and effectively limited as to its effect on deformation of the conductors by respective electrode bars each of which has a land contacting the end of the finger and which has an adjacent recess having a depth approximately equal to the diameter of the respective conductor for contacting the respective finger thereover and having a length which is less than the length of said fingers, said pressing being continued until the electrode lands are spaced from said commutator a distance approximating the thickness of said fingers, characterized by the magnitude of the pressure effecting said pressing and the magnitude of said current for each pressed finger being sufficiently large to completely thermally destroy and peel off the insulation from the conductor under each pressed finger and to cause lateral flow of the peeled off insulation so as to preclude the presence of insulation in the interface of each joined conductor and finger,

said pressure magnitude being less at each finger than that which reduces the sectional shape of the conductor so much as to reduce significantly the strength of the conductor at its connection to the respective finger, and

said current magnitude at each finger being less than that which causes the temperature in the commutator at that finger to be significantly higher than at other fingers during the said fusion welding of all the fingers and conductors and less than that which causes complete melting of the respective conductor.

10. A method of making an armature-commutator assembly comprising the steps of:

connecting a plurality of insulated conductors extending from an armature winding to a respective plurality of projecting commutator fingers having portions bent over the conductors and commutator to hold the conductors between the respective fingers and commutator, and

fusion welding said fingers and conductors by simultaneously pressing each of said fingers onto its insulated conductor and against said commutator with controlled limited conductor deformation and concurrently passing current through each pressed finger and the commutator,

characterized by the magnitude of the pressure effecting said pressing and the magnitude of said current for each pressed finger being sufficiently larger to completely thermally destroy and peel off the insulation from the conductor under each pressed finger and to cause lateral flow of the peeled off insulation so as to preclude the presence of insulation in the interface of each joined conductor and finger,

said pressure magnitude being less at each finger than that which reduces the sectional shape of the conductor so much as to reduce significantly the strength of the conductor at its connection to the respective finger, and

said current magnitude at each finger being less than that which causes the temperature in the commutator at that finger to be significantly higher than at other fingers during the said fusion welding of all the fingers and conductors and less than that which causes complete melting of the respective conductor, wherein the said passing of current through said fingers is effected sequentially to the fingers and wherein at least one of the later fingers in the sequence receives a said current of lesser value than a finger earlier in the sequence to prevent commutator temperature rise.

11. A method as in claim 9 wherein each said finger is coated with a low-melting metal before the respective insulated conductor is connected thereto for providing a more firm fusion welded bond between the respective fingers and conductors so as to make the electrical connection therebetween more stable against oxidation, sulfurization and other corrosion.

12. A method of making an armature-commutator assembly comprising the steps of:

forming a plurality of conductor-engaging fingers on said commutator,

engaging a plurality of insulated conductors led out of an armature winding with engaging portions of said fingers formed by bending end portions of said fingers over the commutator,

deforming the engaged conductors by applying substantially equal pressure to said engaged portions simultaneously by electrode bars corresponding thereto,

limiting the amount of said conductor deformation while said pressure is applied by using electrode bars formed with recesses, each having a depth approximately equal to the diameter of the conductors and each recess superposing a respective conductor, and

supplying currents to said electrode bars while maintaining said applied pressure.

13. A method of making an armature-commutator assembly comprising the steps of:

forming a plurality of conductor-engaging fingers on said commutator,

coating the surface of said fingers with low-melting metal,

engaging a plurality of insulated conductors led out

of said armature winding with said fingers bent over the circumferential periphery of said commutator and said conductors to effect a finger end portion extending beyond each said conductor,

limitedly deforming said engaged conductors by applying pressure simultaneously to all the fingers by electrode bars formed at the engaging end thereof with a land contacting a said finger end portion and with a recess having a depth approximately equal to the diameter of the respective conductor for contacting the respective finger thereover, and

supplying successively decreasing controlled currents to said electrode bars sequentially for fusing said fingers with said conductors, while maintaining said applied pressure, to thermally destroy and peel off the conductor insulation from under the fingers and cause lateral flow thereof and to flatten said finger end portions against said commutator.

14. A method of making an armature-commutator assembly comprising the steps of:

forming a plurality of conductor-engaging fingers on said commutator,

coating the surface of said fingers with low-melting metal,

engaging a plurality of insulated conductors led out of said armature winding with said fingers bent over the circumferential periphery of said commutator and said conductors to effect a finger end portion extending beyond each said conductor,

limitedly deforming the engaged conductors by applying pressure simultaneously to all the fingers by electrode bars formed at the engaging end thereof with a land contacting a said finger end portion and with a recess having a depth approximately equal to the diameter of the respective conductor for contacting the respective finger thereover with said recess superposed over said respective conductor, and

supplying equal valued currents to said electrode bars simultaneously for fusing said fingers with said conductors, while maintaining said applied pressure, to thermally destroy and peel off the conductor insulation from under the fingers and cause lateral flow thereof and flatten said finger end portions against said commutator.

15. A method of making an armature-commutator assembly having an armature winding of insulated wire of very small diameter, comprising the steps of:

forming a plurality of conductor-engaging fingers on said commutator,

coating the surface of said fingers with tin,

engaging a plurality of insulated conductors led out of said armature winding with engaging portions of said fingers,

limitedly deforming said engaged conductors by applying pressure simultaneously to all the engaging portions by electrode bars respectively corresponding thereto, each of said electrode bars being formed at the engaging end thereof with a recess having a depth approximately equal to the diameter of said conductor, and

supplying successively decreasing currents to said electrode bars sequentially for fusing said fingers with said conductors, while maintaining said applied pressure.

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