

SPECIFICATION

A method of drawing a conductor

5 This invention relates to a method of drawing a conductor.

In general, a conductor is employed as a material for an insulated electrical wire, a base material for a metal-plated wire, a constructional material, a decorative material or the like. In order to provide such an element, a large diameter conductor is reduced to a conductor having a desired diameter by wire drawing. In this wire drawing process, lubricant or grease is employed to minimize the friction which is caused when the conductor passes through a die. When the conductor passes through the die, metal powder is created, and hence the metal powder together with the lubricant or grease adheres to the surface of the resultant conductor. Furthermore, when the diameter of the conductor is reduced by the die, heat is generated in the conductor. As a result, scales and modified material layers are created and adhere to the conductor. In addition, oxides formed during conductor storage and dust in the storage area will stick to the conductor.

For instance, in forming a copper wire for use as an insulated electric wire, first a copper rod is formed by casting, and then the copper rod is reduced to a copper wire about 8 mm in diameter. From this copper wire, a variety of copper wires different in diameter are manufactured. For instance, in order to manufacture a copper wire 0.5 mm in diameter from the copper wire about 8 mm in diameter, it is necessary to use several wire draw benches to permit the copper wire to pass through wire drawing dies many times.

Because the copper wire is manufactured in this manner, it appears as if it has a gloss peculiar to copper and nothing is adhering to it. However, if the conductor is wiped with paper, cloth or felt, then it can be detected from the paper, cloth or felt how many materials were actually sticking to the conductor. Furthermore, if the conductor is observed with an optical microscope, then it can be recognized that the conductor is actually very dirty by many materials stuck thereto (hereinafter referred to as "sticking materials" when applicable).

If such a copper wire with sticking materials is used as a conductor for an insulated electrical wire, then the sticking materials can be observed through the insulating film of the insulated electrical wire; that is, the external appearance of the insulated electrical wire is poor. In addition, coating the conductor with paint is obstructed by the sticking material. That is, it is impossible to uniformly coat the conductor with the paint.

If copper powder or scales adhere to the conductor, then corona discharge is liable to occur with the conductor when a voltage is applied thereto and the insulating film characteristic is lowered. In addition, in the case where such a conductor is immersed in solvents or chemicals, the insulating film around the sticking material may be inflated or deteriorated.

If, in metal-plating a copper wire, foreign materials adhere to the copper wire, a uniform plating

thickness cannot be obtained, with the result that the external appearance of the copper wire is poor. Furthermore, the plated metal cannot adhere strongly to any portion of the copper wire where the foreign materials exist, and accordingly it may peel off with the lapse of time.

As is apparent from the above description, it is well known in the art that the foreign materials adhering to a conductor cause various problems in external appearance and characteristic.

Accordingly, a variety of methods of removing foreign materials from a conductor have been proposed in the past. For instance, a method of removing foreign materials from the conductor by wiping it with felt or cloth, a method of degreasing and cleaning the conductor with an organic solvent, and a method of cleaning the conductor by using acid, alkali, ultrasonic waves or electrolyte have been employed.

Of these known methods, wiping with a felt or cloth is unsatisfactory, because the foreign materials adhere to the felt or cloth in a very short time and the felt or cloth becomes useless.

The method of using an organic solvent or its vapor has a degreasing effect. More specifically, in the case where solid materials such as for instance metal powder together with a lubricant, grease, oil or fat adhere to the surface of a conductor, the oil or fat, etc. are dissolved with the result that the metal powder or the like is removed from the surface of the conductor. Thus, the organic solvent cleaning method is effective in removing foreign materials from the surface of the conductor. However, the cleaning effect is insufficient in the case where a high speed operation is required as in a wire draw bench. Therefore, in general metal powder adheres to the surface of the conductor subjected to wire drawing or black points due to a color change of the conductor are found on the surface of the conductor. Moreover, although the cleaning effect of a new organic solvent is significant, it is lost in a short time. Accordingly, it is necessary to strictly control the organic solvent.

In the acid or alkali cleaning method, the metal oxide layer on the surface of a conductor can be dissolved, with the result that metal powder, and oil and fat are removed from the surface of the conductor. Thus, the method is effective in removing foreign materials from the surface of the conductor. However, it is impossible to completely remove foreign materials from the surface of the conductor in this way. Similarly, as in the organic solvent cleaning method, it is necessary to control the acid or alkali solution otherwise the cleaning effect may be lowered.

In the ultrasonic cleaning method, foreign materials are removed from the surface of the conductor by vibration. Accordingly, the method is effective in removing relatively large foreign materials or solid materials loosely adhering to the conductor. However, as in the above-described cleaning methods, the ultrasonic cleaning method is not particularly effective in removing oil and fat or foreign material strongly adhered to the conductor.

The ultrasonic, organic solvent, acid and alkali

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cleaning methods may be combined to fully utilize their effects. However, in this case also, metal powder and black points due to a change in color of the conductor have been found on the surface of the conductor subjected to wire drawing.

Furthermore, in each of the above-described cleaning methods, the amount of conductor breakage experienced during wire drawing is not reduced. Moreover in these conventional methods, the acid, alkali or organic solvent becomes mixed with the lubricant during the cleaning operation, so that deterioration of the lubricant is accelerated, and it is impossible to increase its service life.

An object of the present invention is therefore to overcome or alleviate the above-mentioned problems experienced in the prior art.

Accordingly, the invention resides in a method of drawing a conductor having a diameter not exceeding 0.10 mm, comprising the steps of subjecting said conductor to electrolytic cleaning by passing an electric current between said conductor and an electrode in an electrically conductive liquid while the conductor is moved through said electrically conductive liquid, and thereafter subjecting said conductor to wire drawing, wherein prior to the electrolytic cleaning step, the conductor is softened by the passage therethrough of the electric current used for the electrolytic cleaning.

The invention will be described with reference primarily to a copper wire but it is to be appreciated that the invention is not limited to copper wire. That is, the invention is applicable to all kinds of metal wire such as copper alloy wires, aluminum wires, aluminum alloy wires, iron wires, piano wires and metal-plated wires.

Thus, according to the invention, a conductor is subjected to wire drawing after being subjected to electrolytic cleaning. The resultant conductor has no copper powder or black points due to the color change of the conductor on its surface. Furthermore, the frequency of conductor breakage during wire drawing is reduced, and the wire drawing characteristics are remarkably improved. The service life of the lubricant is increased to about one month from one week service life typically experienced with prior art methods. Previously a continuously operated wire drawing die required repolishing after about one week whereas using the method of the present invention, the die can be used without repolishing for about two to five weeks. Further, with electrolytic cleaning the cleaning effect is maintained unchanged for a long period of time, and control of the cleaning liquid can be readily achieved.

In the electrolytic cleaning method, metal powder is mechanically removed from the surface of the conductor and any film of oil or grease is broken down by hydrogen or oxygen gas generated at the conductor. As a result, a cleaned conductor is provided. The electrolytic cleaning method is advantageous in that not only the oil or grease, and foreign materials are removed from the surface of the conductor, but also the metal oxide film is simultaneously removed from the surface of the conductor.

A cathode method in which a conductor to be treated is connected as the cathode of an electrolytic

cell and an anode method in which a conductor to be treated is connected as the anode of a cell are, in general, separately carried out. However, these two methods may be employed in combination.

This invention is most effective when the cathode method is employed i.e., in the case where a conductor is connected as the cathode of an electrolytic cell.

In this invention, before being subjected to wire drawing i.e. after being fed out of a supply reel, a conductor is cleaned. However, if the conductor is cleaned before it is fed out of the supply reel, then foreign materials can be more effectively removed from the surface of the conductor, and black points, or the color change of the conductor are more positively eliminated from the surface of the conductor. In addition, the wire drawing characteristics, the service life of the wire drawing die and the service life of the lubricant will be further improved.

The reasons for improvement of the wire drawing characteristics and the service lives of the wire drawing die and the lubricant by removing foreign materials from the conductor before it is subjected to wire drawing will now be considered. If the conductor has foreign materials adhering to its surface when the diameter of the conductor is reduced by the wire drawing die, then the friction between the conductor and the die is increased with the result that greater force must be used to draw the conductor through the die. Accordingly, metal powder is liable to be creased as the conductor is passed through the die and the metal powder together with the lubricant adheres to the surface of the conductor.

The pulling force at the die is reduced by about 10 to 20% by removing foreign materials from the surface of the conductor. Especially, in the case of manufacturing an extremely thin wire less than 0.08 mm in diameter, the pulling force at the first die is reduced by 20 to 25%. In general, the pulling force at a die is 50% of the breaking strength of a drawn wire, and it is believed that the amount of conductor breakage is reduced by decreasing the pulling force.

It is considered that, as the foreign materials on the surface of the conductor are not mixed with the lubricant, the lubricant is deteriorated at a lower rate, with the result that its function as lubricant is maintained unchanged for a longer period of time.

Removal of foreign materials also reduces die wear because of the decreased pulling force required to draw the conductor through the die, with the result that the service life of the die is increased. Typically, the service life of the first die is increased by a factor of about two.

The electrolyte used in electrolytic cleaning may be an electrically conductive liquid such as an alkali salt solution obtained by dissolving sodium carbonate, caustic soda, sodium silicate, sodium phosphate, sodium bicarbonate, or salt in water, or an acidic solution obtained by dissolving acid such as hydrochloric acid, sulfuric acid, nitric acid or oxalic acid in water. Alternatively, the electrolyte may be an electrically conductive liquid prepared by mixing a plurality of alkali salts or acids instead of using merely a single alkali salt or acid.

In the case of the cathode method, a metal anode placed in the electrolyte is dissolved therein, accord-

ing to the anode oxidation principle, by the current induced by the application of voltage. The dissolution of the metal anode is one of the factors which deteriorates the electrolytic cleaning liquid. Accordingly, it is desirable to prevent the dissolution of the metal anode. Therefore, it is preferable that the metal anode placed in the electrolyte is, for instance, a stainless steel plate. Furthermore, it is desirable that the electrolytic cleaning liquid is a sodium carbonate solution instead of a salt water which corrodes metal.

The density of current flowing in the surface of the conductor can be varied according to the degree that the foreign materials are removed from the surface of the conductor. The current density may be from 0.1 to 50 mA/mm². However, in general, the foreign materials can be substantially completely removed from the surface of the conductor with a current density of from 0.5 to 20 mA/mm². However, it should be noted that the current density is not limited to the above-described value.

It is preferable that the conductor is washed with water after being passed through the electrolytic cleaning bath.

The accompanying drawing illustrates a method of drawing a conductor according to one example of the invention.

Referring to the drawing, in the method of said one example a conductor 2 fed from a supply reel 1 is subjected to electrolytic cleaning in an electrolytic cleaning bath 3 containing an electrolytic cleaning liquid. In the drawing the reference numeral 4 designates a DC power supply unit, the numeral 5 designates an anode and the numeral 6 designates a terminal for supplying current to the conductor. The conductor subjected to electrolytic cleaning is introduced into a water cleaning bath 7 to remove any residual electrolyte and is then fed to a wire drawing bench 8 provided with capstans 9 and 10 and a wire drawing die 11. The conductor which has been reduced in cross section by the wire drawing die is then wound around a take-up reel 12.

The invention includes a technique of softening a conductor by utilizing the current which is employed for the electrolytic cleaning. Before the conductor is introduced into the electrolytic cleaning bath, it is softened by the current at a position between the supply reel and the electrolytic cleaning bath. Immediately after this, the conductor enters the electrolytic cleaning bath to be subjected to electrolytic cleaning. That is, the conductor which has been softened and has no foreign materials adhering to its surface is subjected to wire drawing. The effects of this step will now be described.

If, instead of a hard copper wire, a soft copper wire is employed, the convolutions of wire on the supply reel may slightly adhere to one another as the wire is fed from the supply reel, with the result that it is often difficult to supply the wire smoothly, i.e. the tension of the wire often fluctuates. If the wire is small in diameter, the fluctuation in tension frequently causes breakage of the wire. In contrast, hard copper wire can be smoothly fed out of the supply reel and it does not significantly fluctuate in tension. However, soft copper wire is more prefer-

able for the following reasons. Soft copper wire can be drawn with a smaller pulling force. With soft copper wire, the tendency for wire breakage can be reduced, and the wire can be readily drawn. According to this embodiment of the invention, a hard copper wire is supplied from the reel, but it becomes a soft copper wire before subjected to wire drawing. Thus, the wire drawing method according to this embodiment is advantageous in that the merits of both soft and hard copper wires are fully utilized, the frequency of conductor breakage is considerably decreased, and the yield is markedly improved.

When a conductor is softened by current, its color may be changed. However, the color change can be eliminated completely while the conductor is in the electrolytic bath. Furthermore, a method in which an inert gas is employed while the conductor is softened by current may be used to prevent the color change. Thereafter, the conductor is passed through a die having a predetermined diameter and the conductor is reduced to a desired size.

The method according to the invention provides an advantage in quality since no foreign material adheres to the surface of the conductor subjected to wire drawing, and the following advantage in productivity is obtained.

In drawing a conductor less than 0.10 mm in diameter, instead of a wet type wire drawing method in which the capstans are wetted by a lubricant, a dry type wire drawing method in which the capstans are not wetted may be employed.

The invention is very effective with the dry type wire drawing method. In drawing a conductor which has not been cleaned, tacky metal powder together with the lubricant adheres to the capstans 9 and 10 in the drawing, and therefore the conductor running between the capstans cannot slip freely on the capstans. The result is that the conductor is vibrated. This vibration greatly changes the tension of the conductor and as a result, the conductor may be broken. Accordingly, in the past when using a wire drawing bench, it was necessary to periodically remove the metal powder from the capstans by using felt or a knife.

On the other hand, in the method of the invention, the conductor is cleaned. Therefore, the amount of metal powder adhering to the capstans is extremely small, with the result that the number of conductor breakages and the frequency with which the capstans must be cleaned is reduced.

For instance, using conventional wire drawing techniques to reduce a copper wire 0.040 mm in diameter to a copper wire 0.025 mm in diameter, it was necessary to remove the copper powder from the capstans once every thirty minutes. However, in the case of drawing the same copper wire subjected to electrolytic cleaning, no copper powder adhered to the capstans, that is, it was unnecessary to remove any copper powder. Furthermore, the winding weight was 1.5 to 2.5 Kg at maximum before the conductor was cleaned, but it was increased to 3.0 to 6.0 Kg according to the invention.

The increment in winding weight contributes greatly to the productivity of the process.

According to the invention, as was described pre-

viously, the lubricant is free from contamination, with the result that the service life of the lubricant is increased, and the pulling force at the wire drawing die can be reduced. Hence, the service life of the wire drawing die is lengthened two to four times as compared with that of a wire drawing die in the conventional methods. Thus, the wire drawing method according to the invention contributes to reduction in manufacturing costs.

- 10 The invention will be further described with reference to the following Example and Comparison Example:—

Comparison Example

- 15 A copper wire 0.080 mm in diameter was reduced to a copper wire 0.040 mm in diameter by using a wire drawing bench. Ten dies were used. The wire winding rate was 800 m/min.

- Since during the wire drawing process, tacky copper powder adhered to the capstans to vibrate the wire, the copper powder had to be removed from the surface of the capstans by wiping with felt and a razor every thirty minutes. With an optical microscope at forty magnification, it was observed that a number of small and large copper particles and black modified materials were stuck to the surface of the wound wire. The average winding height was 1.7 Kg. Replacement of the lubricant was required after about two weeks, whereas it was necessary to replace the first die and the last finishing die after about one week.

Example

All the data are the same as in the Comparison Example except for the following:

- Before being subjected to wire drawing, the wire was passed through an electrolytic cleaning bath (30 cm in length) containing a 0.5% sodium carbonate solution. The conductor was employed as the cathode, while the electrode in the cleaning bath was employed as the anode and a DC voltage was applied between the electrodes so that the current density at the surface of the wire was 10 mA/mm². After this electrolytic cleaning, the conductor was cleaned with water and was then subjected to wire drawing. No copper powder adhered to the capstans, and accordingly it was unnecessary to remove copper powder from the capstans during the process. No copper particles and modified materials were found on the surface of the wound conductor. The wire winding weight was about three times that in the Comparison Example. The lubricant was replaced after about twenty days, and it was necessary to change the first die and the last finishing die after about ten days.

- In this Example, the wire was softened before being subjected to the electrolytic cleaning by passing a current of 2.4A through the wire.

CLAIMS

1. A method of drawing a conductor having a diameter not exceeding 0.10 mm, comprising the steps of subjecting said conductor to electrolytic cleaning by passing an electric current between said conductor and an electrode in an electrically conductive liquid while the conductor is moved through said electrically conductive liquid, and thereafter subjecting said conductor to wire drawing, wherein

prior to the electrolytic cleaning step, the conductor is softened by the passage therethrough of the electric current used for the electrolytic cleaning.

2. A method as claimed in Claim 1, wherein said conductor defines the cathode in the electrolytic cleaning step.

3. A method as claimed in Claim 1 or Claim 2, wherein said electrically conductive liquid is an alkali salt solution or an acid solution.

4. A method as claimed in any one of Claims 1 to 3, wherein during said electrolytic cleaning, the current density at the surface of said conductor is between 0.1 and 50 mA/mm².

5. A method as claimed in any preceding Claim wherein after the electrolytic cleaning step, said conductor is cleaned with water.

6. A method as claimed in Claim 1, of drawing a conductor having a diameter not exceeding 0.10 mm substantially as hereinbefore described with reference to the accompanying Example.

7. A conductor drawn by a method as claimed in any preceding Claim.

Printed for Her Majesty's Stationery Office by The Tweeddale Press Ltd., Berwick-upon-Tweed, 1982.

Published at the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.



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Example

All the data are the same as in the Comparison Example except for the following:

Before being subjected to wire drawing, the wire was passed through an electrolytic cleaning bath (30 cm in length) containing a 0.5% sodium carbonate solution. The conductor was employed as the cathode, while the electrode in the cleaning bath was employed as the anode and a DC voltage was applied between the electrodes so that the current density at the surface of the wire was 10 mA/mm². After this electrolytic cleaning, the conductor was cleaned with water and was then subjected to wire drawing. No copper powder adhered to the capstans, and accordingly it was unnecessary to remove copper powder from the capstans during the process. No copper particles and modified materials were found on the surface of the wound conductor. The wire winding weight was about three times that in the Comparison Example. The lubricant was replaced after about twenty days, and it was necessary to change the first die and the last finishing die after about ten days.

In this Example, the wire was softened before being subjected to the electrolytic cleaning by passing a current of 2.4A through the wire.

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