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O. M. OTTE

2,260,398

TRANSFORMER

Filed May 25, 1939

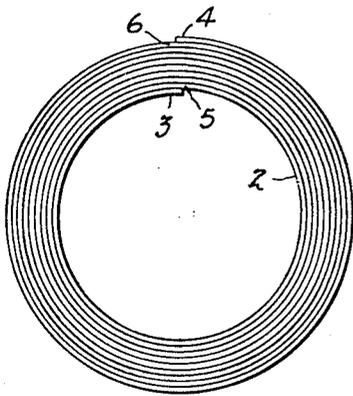


Fig. 1

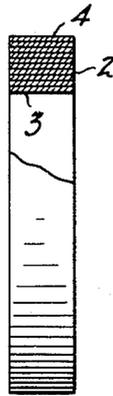


Fig. 2

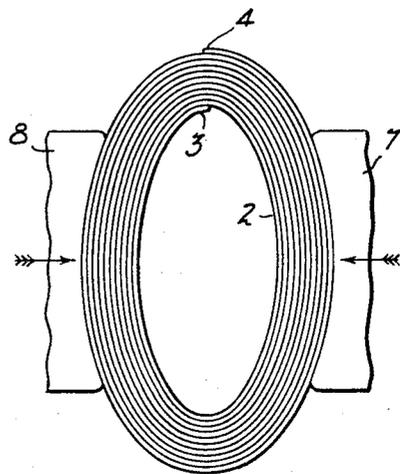


Fig. 3

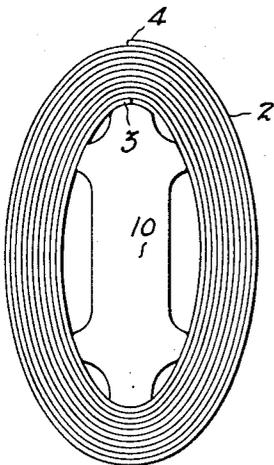


Fig. 4

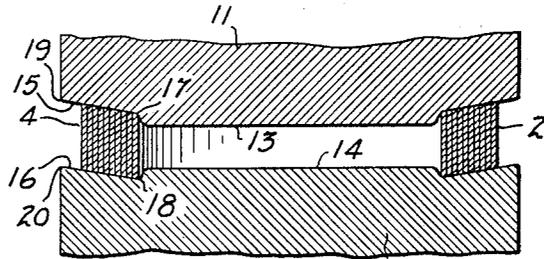


Fig. 5

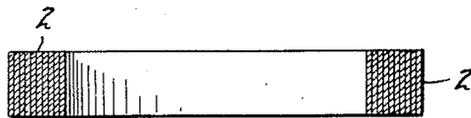


Fig. 6

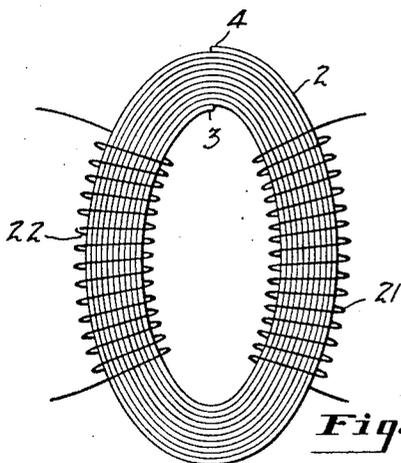


Fig. 7

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2,260,398

TRANSFORMER

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Application May 25, 1939, Serial No. 275,697

5 Claims. (Cl. 175-356)

This invention relates to transformers and, in particular to transformer cores having low watt loss and of a type especially suitable for distribution transformers.

An object of this invention is to provide a transformer core which has a relatively low watt loss.

Another object of this invention is to provide a transformer core in which the metal has relatively little strain, and which is in a form suitable for being wound by automatic winding machines without imparting stress to the core.

A still further object of this invention is to provide a transformer having a core which consists of a single strip of silicon steel, in which the magnetic circuit is a continuous metallic path.

Other objects will be apparent from the following description of the invention, as illustrated in the accompanying drawing where:

Figure 1 is a side elevation of a spirally wound strip of silicon steel having sufficient length and cross-section to form a suitable transformer core;

Fig. 2 is a view of the spiral of Fig. 1, with a portion broken away and shown in section;

Fig. 3 is a diagrammatic view showing the spiral of Fig. 1 pressed between the platens of a press to the shape desired for the finished core;

Fig. 4 is a side elevation of the flattened core of Fig. 2, with a strut inserted to hold the coil in the flattened condition.

Fig. 5 is a sectional view showing the annealed core inserted in a press designed to break any adhesion between successive laminations or layers of the spiral;

Fig. 6 is a section through the annealed core after it has been removed from the press of Fig. 5 and the lamination or turns of the spiral realigned; and

Fig. 7 is a diagrammatic view of a transformer provided with a completely annealed elongated core.

In the development of cores formed of silicon steel strip material it has been found that the magnetic permeability of the material in a direction parallel to the grain of the material, and longitudinally of the strip, is considerably higher than in a crosswise direction. It was also found that in such strip core material the maximum permeability was increased above that of the silicon sheets made by cross rolling in the usual manner. It has been commonly believed heretofore that the watt loss of transformers

having a spiral strip core was decreased by an annealing treatment, in which a portion of the strain occasioned by the rolling of the metal or coiling of the core remained in the spiral strip core to obtain improved magnetic properties. In order to effect this, the wound core was either annealed at temperatures such as 350° F. or so, which would only relieve part of the strain in the metal or it is deformed to some extent after the annealing treatment.

In another process heretofore used for making transformer cores the strip material was wound in spiral shape to form a coil having the size and shape of the transformer core, and then annealed to reduce or eliminate the strains present in the material. This coil or core was then opened up and rewound about form-wound copper coils. The opening up and rewinding of the finally annealed spiral steel core introduces strain in the metal.

According to the present invention, electrical transformers having superior magnetic properties may be produced with an annealed core of suitable silicon steel closely wound in spiral shape, in which core substantially no strain is introduced after the final anneal.

As illustrated in the drawing, a strip of silicon steel having a suitable width and length to produce a transformer core of the desired size is spirally coiled, as shown in Fig. 1, to produce the spiral coil 2 having end portions 3 and 4. The spiral coil is wound under considerable tension, and the inner end portion 3 and the outer end portion 4 are preferably tacked, as by welding, to the adjacent inside and outside layers of metal 5 and 6, respectively. The length and cross-sectional area of the spiral core desired in a transformer of a given rating may be calculated according to the procedure well known in the art, so as to provide a magnetic path having the desired reluctance and sufficient length to provide room for the necessary windings.

While a round or annular core may be used in the manufacture of transformers having form-wound copper coils, when the copper coils are to be wound about a core, the core may be of any desired shape to facilitate low cost of manufacture and economy of space. It is frequently desirable to have the core of an oval or ellipsoidal shape, or it may even approach an oblong shape. The shape may be varied for many reasons and, when the core is to have the copper coils wound around it by automatic winding machinery, the precise shape of the core is not limited, as the winding machinery will wind the copper wire

thereon, whether the core be circular, oblong, or ellipsoidal.

By deforming the annular core to a flattened or elongated shape, the application of insulation to the core is greatly facilitated. Also, the transformer may have the core so shaped as to adapt it advantageously, when wound, to any desired shape or type of case.

The annular coil 2 of Figs. 1 and 2 is inserted between the platens 7 and 8 of a suitable press, and deformed to an oval or ellipsoidal shape by movement of the platens in the direction of the arrows of Fig. 3. It has been found that the round coil may be elongated to a considerable degree, such as shown in Fig. 3, without causing separation of the laminations, a close engagement between laminations being desirable for the production of a transformer having quiet operation.

While the spiral core is held in its shaped condition by the press of Fig. 3, a strut 10 is inserted to maintain the shape of the core during the annealing. The strut 10 is of a material which will not melt or fuse at annealing temperatures, and may be a refractory or ceramic material, and is held in the shaped coil by the spring tension of the metal, until the core is annealed, when it becomes set to the final shape.

The shaped coil or core of Fig. 3, having the strut therein, is transferred to an annealing furnace, where the temperature of the core is raised sufficiently high to anneal the metal. The optimum annealing temperature varies with the silicon content of the steel used, but for steel with the higher silicon content, it will be around a temperature such as 1700° F. or 1800° F. and with steels having about 3.5% silicon, the annealing range ordinarily commercially used is from about 1450° F. to 1650° F. The temperature and time necessary for the proper annealing of the core depend upon such factors as the silicon content of the steel used, and the size and weight of the core, etc. Thus, with steels of higher silicon content, a higher annealing temperature appears desirable, and with larger cores a longer annealing time is necessary for all the metal to come to the proper temperature. In order to secure the best electrical efficiency, attention must be given to obtain the proper annealing temperature for the particular kind of steel being annealed. The cores are preferably annealed for a sufficient time, at a suitable temperature, to substantially remove the strains from the metal, and, after being annealed, the core will retain its shape, so that the strut 10 may be easily removed.

The annealed core of Fig. 4 may have developed, during the annealing process, some adhesions between individual turns of the metal, or between successive layers of the metal, even though the surfaces of the metal of the core may have been coated, as is customary, with separating or insulating material, such as magnesium oxide, and prior to winding the spiral 2 of Fig. 1. To provide low eddy current losses it is desirable that any such adhesions that may have occurred during annealing be broken, and, in order to obtain the improved core of this invention, these adhesions should be broken without permanently straining the metal.

The annealed and flattened core of Fig. 4 may have any adhesions removed without producing permanent strain in the metal by inserting the annealed core in a press having platens 11 and 12 of the type shown in Fig. 5. The platens 11 and 12 have raised portions 13 and 14, respective-

ly, having an outline form similar to the opening or window in the annealed core to center the core between the platens 11 and 12. The platens 11 and 12 are provided with portions 15, 16 having cooperative inclined surfaces, the inclination being indicated by the pitch of the lines 17, 18, and 19, 20, respectively.

When the annealed coil 2 is inserted between the surfaces 15 and 16 of the platens 11 and 12, and suitable pressure is applied, a slight movement between adjacent laminations or turns of the core takes place. The inclination of the surface portions 15 and 16, respectively, is preferably just sufficient to cause rupture of any adhesions. A relative vertical movement for common types of cores between the inside and outside turns of a half inch or so usually suffices. As this small movement is distributed throughout the whole length of the spirally coiled strip forming the core, which may be 200 feet or more, it may be seen that no appreciable strain is imparted to any portion of the metal, and that any strain that may be imparted is not permanent.

Upon removal of the core 2 from the press, any slight set that may have been occasioned by engagement between the inclined surfaces of the press platens may be readily removed on a flattening table or the like.

Primary and secondary windings 21 and 22 are then wound around the core by any suitable mechanism, or by hand if desired. The windings 21 and 22 are preferably applied to the longer sides of the oval core, which may be only slightly curved over a considerable portion of their length. A relatively straight or slightly curved shape is usually desirable for receiving the copper winding, because adequate insulation, both between the individual turns of the windings and between the windings and the core, may be more easily applied.

While the windings have been diagrammatically shown in Fig. 7 with one on each side of the core, it is to be understood that the windings may be of any type, such as having the primary and secondary superposed, or otherwise arranged.

While an improvement in transformer efficiency results when a transformer core formed from a metal strip of a given silicon content is produced as above described, it has been found that a further improvement in transformer efficiency occurs when the silicon steel used has been rolled unidirectionally, that is, passing through the reducing rolls in the same sense.

In preparing the preferred silicon steel for use in the type of transformers herein described, the ingot having the desired silicon content is removed from the ingot mold and heated to a uniform temperature in the usual manner, and is passed through the blooming mill, and subsequent roll mills, in a single longitudinal direction, that is, in the same sense, until metal of requisite thickness is obtained. A back-and-forth rolling of the metal at any time in the preparation of the steel sheets or strip material is found to adversely affect the electrical properties of the silicon steel, and to obtain the most improved magnetic properties the metal of the ingot first presented between the rolls of the blooming mill should be presented to the bite of subsequent rolls at each reducing pass in the further processing of the metal.

It has also been found, when substantially all of the rolling is in the same sense, that the magnetic properties of the steel have been improved, even though the optimum properties are produced by

a process wherein all the rolling in which substantial reduction is effected is in the same sense. When a reversing mill is used for reducing the gauge of the metal, the metal should be turned end-for-end each time the mill is reversed, so that the end portion of the strip first reduced in the blooming mill will first enter the bite of the rolls in subsequent reducing passes. If desired, the rolls of a reversing mill may be separated, so that when the mill is operated in reverse the metal may be conveyed in a dead pass to the starting position for an additional reducing pass there-through.

While deformed spiral cores may be produced by first winding a round spiral core as above described and elongating it, it is contemplated that the core may be wound in the desired elongated shape as the strip is finished and coiled at the mill or at any time prior to final anneal. If the core material is wound in the elongated spiral shape, or in the shape desired in the final transformer, it may be held in its wound form, by an insert, to maintain its shape prior to and during the annealing.

It is preferable to form the core from a single, continuous strip but it may be seen that a plurality of strips may be used to form the core coil, in which case the ends of the strips may be secured to each other or to adjacent layers.

The core loss of transformers produced as herein described is considerably reduced. The most efficient transformer cores are prepared, as above described, from steel rolled in a single sense from the ingot to the sheet or strip, as described in my application Serial No. 275,696, filed May 25, 1939. Even when conventional strip material is used, however, improvement in the electrical efficiencies of transformers made according to the present invention are obtained. This is largely on account of the fact that there have been no substantial or permanent strains introduced into the metal of the transformer core between the time that such core is finally annealed and the time that the transformer is finished ready for use.

It will be seen that transformers made according to the present invention may have cores of various desirable shapes and sizes to meet special conditions, and the manufacture of transformers of standard design, shape, capacities, etc., is facilitated. It is also to be noted that, due to the processes of manufacture, the silicon steel may contain considerably more than 3% silicon.

Furthermore, if the metal from which the transformer core is made has been elongated in one direction only, as is accomplished by rolling in one sense substantially from the ingot to the finished sheet or strip, it will have a crystal axis or grain arrangement that makes it more efficient for transformer use. Also, by introducing no substantial or permanent strains in the metal forming the transformer core, after the core has been shaped, and finally annealed, the efficiency of the transformer is improved.

In the application, "hot rolled relatively thin silicon steel strip" is intended to refer to thin silicon steel strip which has been substantially

entirely reduced by hot rolling, as by rolling thicker strip in pack form, as set forth in my above mentioned copending application.

The principles of the present invention may be utilized in various ways, numerous modifications and alterations being contemplated, substitution of parts and changes in construction being resorted to as desired, it being understood that the embodiments shown in the drawing and described above are given merely for purposes of explanation and illustration without intending to limit the scope of the claims to the specific details disclosed.

What I claim is:

1. A transformer core having a substantially uniform cross sectional area comprising a continuous strip of thin silicon steel, the metal of said strip having the crystal axis orientation and grain arrangement characteristic of a strip which has been substantially entirely reduced and elongated in the same sense.

2. A transformer having a core comprising a strip of relatively thin silicon steel wound spirally to form a coil with an opening to receive windings and having the crystal axis orientation grain arrangement and magnetic properties characteristic of silicon steel that has been formed from an ingot by rolling the metal stock in one direction without back and forth rolling.

3. A transformer having a core comprising a strip of substantially completely annealed, relatively thin silicon steel wound spirally to form a coil having substantially uniform cross sectional area and an opening to receive windings, said strip having the grain arrangement and magnetic properties characteristic of silicon steel that has been formed from an ingot by elongating the metal only by rolling it in a single sense without back and forth rolling, the metal of the core being in the physical condition resulting from having had no deformation effecting any appreciable change in the radius of curvature of the individual turns of the spiral after the annealing.

4. A transformer having a core comprising a single strip of substantially completely annealed, relatively thin silicon steel wound spirally to form a coil of elongated shape having substantially uniform cross sectional area and an opening to receive the windings, said strip having the grain arrangement and magnetic properties characteristic of silicon steel that has been formed from an ingot by elongating the metal only by rolling it in a single sense without back and forth rolling, the metal of the core being in the physical condition resulting from having had no deformation effecting any appreciable change in the radius of curvature of the individual turns of the spiral after the annealing.

5. A transformer core comprising a substantially completely annealed strip of thin silicon steel, spirally wound and forming a coil of elongated shape, the metal of said strip having the crystal axis orientation and grain arrangement characteristic of a strip which has been substantially entirely reduced and elongated in the same sense.

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