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INDUCTANCE CORE HAVING LOW NEGATIVE TEMPERATURE COEFFICIENT OF INDUCTANCE AND METHOD OF MAKING IT

Paul Gottschalt, Berlin-Spandau, Germany, assignor to Siemens & Halske Aktiengesellschaft, Siemensstadt, near Berlin, Germany, a corporation of Germany

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The invention relates to a method for producing coil cores of magnetizable material.

For numerous purposes in the field of electrical communication, inductance coils are required, the inductance of which must not change more than to an extremely slight degree for long periods of time (T). In addition, it is often necessary to make exacting demands with respect to the temperature coefficient

$$\alpha_L = \frac{1}{L} \frac{\partial L}{\partial T}$$

of the inductance (L). There are cases where as small a temperature coefficient as possible is desired, for instance, $\alpha < 1 \times 10^{-5}$ degree⁻¹; but more often it is required that the temperature coefficient come as near as possible to a certain pre-given value, for instance, $\alpha = -3 \times 10^{-5}$ degree⁻¹. Such a given value, usually negative, of the temperature coefficient is required especially in such cases where the coils are to be arranged in oscillating circuits, band filters and similar connections with condenser circuits, and where the natural frequencies of these coil-condenser-circuits are supposed to have a high constancy and a slight dependence on temperature. These natural frequencies f_0 depend, in general, on the inductance (L) of the coil and the capacity (C) of the condenser in accordance with the relation

$$f_0 = \frac{1}{2\pi\sqrt{LC}} \quad (1)$$

The often necessary high constancy of the natural frequency f_0 is obviously attained if—

(1) L and C at any maintained temperature T remain unchanged in time within the temperature range met with in regular service, and if

(2) Within this entire range of temperature the temperature coefficient

$$\alpha_L = \frac{1}{L} \frac{\partial L}{\partial T}$$

of the coils with reversed signs corresponds to that of the temperature coefficient

$$\alpha_C = \frac{1}{C} \frac{\partial C}{\partial T}$$

of the condenser, viz., if the relation

$$\alpha_L = -\alpha_C \quad (2)$$

is complied with.

Since the temperature coefficient of a condenser can, in general, be intentionally influenced only by comparatively troublesome and expensive measures, it is usually endeavoured to satisfy the

relation (2) by arrangements at the coil, which offers more technical possibilities than is the case with the condenser.

The temperature coefficient of the condensers mostly in use in technical engineering is in general positive in accordance with the linear coefficient of expansion of the material employed, so that in most cases a negative temperature coefficient of the coil must be required. For instance, the frequently used mica condenser in ambient air may have the coefficient $\alpha = +3 \times 10^{-5}$ degree⁻¹, so that for the coils to be connected with such condenser the coefficient $\alpha = -3 \times 10^{-5}$ degree⁻¹ is prescribed.

However, the usual coils employed in electrical communication, in particular the coils without ferromagnetic core, such as are common for very high frequencies (short waves), show in the great majority of cases a positive temperature coefficient α_L . With such coils, therefore, special technical measures are necessary for obtaining a certain pre-given negative temperature coefficient, for instance, -3×10^{-5} degree⁻¹. A number of such measures are known, yet they have considerable drawbacks, or are only suitable for a greatly limited special use of the coils.

The invention does away with these disadvantages. According to the invention the magnet core of inductance coils designed to meet the aforementioned requirements, is produced by mixing ferromagnetic powder and an insulating substance, and/or several ferromagnetic kinds of powder with differing temperature coefficients, and/or several thermoplastic binding materials, while maintaining a mutual proportion resulting in a total temperature coefficient of pre-given small value, and by squirting the thus prepared mixture to obtain the desired shape of the core.

According to a preferred embodiment of my invention, the ferromagnetic portion of the mixture to be squirted consists of carbonyl iron powder or contains carbonyl iron powder as the major component, i. e. in an amount of at least 50% as compared with the total weight of the ferromagnetic portion. Especially favorable results are obtained with 50 to 80% carbonyl iron powder and 50 to 20% of an iron-nickel alloy of high magnetic permeability. The latter alloy may consist of about 78.5% nickel, the remainder iron. The insulating binder to be mixed with the ferromagnetic portion may consist of thermoplastic materials, preferably polystyrol and the like. The binder is to be used in a proportion of 1/10 to 5/10 as compared with the weight of the ferromagnetic portion. If normal polystyrol is employed, propor-

tions between 2/10 and 5/10 have proved favorable, while when polystyrol of higher molecular weight is used, a proportion between 1/10 and 3/10 is preferable.

5 For elucidating the invention, some comparative examples of differently produced mass cores commonly used for Pupin coils, and the dependence of the inductance on the temperature for a number of temperature changes are referred to in the following. As Example No. 1, a core made of carbonyl iron powder and insulated by organic substances is taken in view; and as Example No. 2 a core made of ferro-nickel alloy powder, which has been insulated with glow-resistant inorganic substances, and after the pressing has been annealed in known manner at about 500°.

A mass core according to Example No. 1, is unsuited for coils of high constancy from the outset, owing to its considerable want of reproductive capacity, i. e. the material and permanent alterations after repeated changes of temperature. The temperature coefficient, while negative, is too large ($\alpha_L = -17 \times 10^{-5}$ degree $^{-1}$). In the case of Example No. 2, the want of reproductive capacity is considerably less, but the temperature coefficient is highly positive

$$(\alpha_L = +23 \times 10^{-5} \text{ degree } ^{-1})$$

It has further been found, that the constancy in time of all those cores, which have been produced by mechanical pressing together of the insulated powder, cannot be increased at all, or only under considerable difficulties, to the extent frequently required.

35 While it is known to produce mass cores not by purely mechanical pressing-together, but by die casting, such mass cores do not offhand yield the low magnitudes of the temperature coefficient required in each case. It has however been found—and this recognition forms a basis of the present invention—that with cores produced by the die casting method in fact a better constancy in time can be attained, than with the cores produced up to now principally by the pressing method.

As Example No. 3, a magnet coil may be considered, having a core squirted in known manner of carbonyl iron. Such a coil shows fewer changes in its inductance with repeated changes of temperature, i. e. the want of reproductive capacity is greatly reduced as compared with that according to Example No. 1. The temperature coefficient is, in fact, negative, as generally required, but not to the desired amount of about

$$\alpha_L = -3 \times 10^{-5} \text{ degree } ^{-1}$$

As compared with the foregoing three types of cores, a material advance with respect to constancy in time and reproductive capacity, together with a low magnitude of the temperature coefficient, is obtained if the cores are produced according to the invention by employing certain mixture proportions and producing the cores by squirting. An inductance coil having such a core, shows, for instance, a temperature coefficient of the desired value $\alpha = -3 \times 10^{-5}$ degree $^{-1}$, and suffers practically no changes of this value during a period of several months, i. e. such changes remain materially below $\pm 1 \times 10^{-4}$.

A method of producing such cores is the following. 60% carbonyl iron powder is mixed with 40% powder of a ferro-nickel alloy containing 78.5% nickel contents. This powder mixture is pre-insulated in the usual manner with a thin layer of insulating material, then mixed with 15 weight units of polystyrol powder and eventually

formed in known manner into annular cores by squirting. By altering the mixture proportions, i. e. of the iron and alloy mixture or of the metal and polystyrol mixture or of both proportions, the temperature coefficient can be changed at will within limits wide enough to allow satisfying all conditions actually occurring in practice. In each particular case, the most favorable mixture proportions may be computed by an interpolation based upon the measured temperature coefficients of known cores with similar mixture proportions, or may be newly determined by measurements of cores with differing mixture proportions.

In order to obtain as high permeabilities as possible, it is preferable to choose as high a share of ferromagnetic powder as possible, as long as this does not noticeably impair the capability of being squirted, and to vary the magnitude of the temperature coefficient by correspondingly varying the mixture proportion between two differing kinds of ferromagnetic powder.

But there exist also fields of application, in particular with regard to coils for very high working frequencies, for instance short waves, where very slight permeabilities are desired owing to the unavoidable losses in the iron core increasing with the frequency. In cases of this nature the required temperature coefficient can be obtained by using a greater share of insulating material, or also, without the use of different kinds of ferromagnetic powder, merely by exactly maintaining a mixture proportion between a ferromagnetic powder and a thermoplastic mass, which proportion may be determined in a given case, for instance, by some tests made with cores of different mixture proportions.

Surprisingly favorable results are obtained not only by the heretofore customary polystyrol, but by similar thermoplastic masses, which, however, have a higher thermal stability. Squirted mass cores of carbonyl iron powder and a polystyrol, having an extremely high mean molecular weight of, for instance, more than 100,000, resulted in very slight temperature coefficients and a good constancy in time. Coils with annular cores made of a mixture with 15 weight units of this polystyrol to 100 units of iron showed by measurements the small value $\alpha_L = -4 \times 10^{-5}$ degree $^{-1}$, and coils with other core shapes of the same core substance showed values between $\alpha_L = -2 \times 10^{-5}$ degree $^{-1}$ and $\alpha_L = -5 \times 10^{-5}$ degree $^{-1}$.

Further, the temperature coefficient may also be affected in the manner desired by the simultaneous use of different thermoplastic masses in certain mixture proportions, for instance, by mixing a part of the said polystyrol, having a high molecular weight, with normal polystyrol. The use of polyvinyl-carbazal has also yielded very good results.

Physical examinations conducted in order to find an explanation of the causes for the improvement obtained by the invention, have shown that the better constancy in time and the improved reproductive capacity of the cores is due to the thorough bond of the iron powder with the insulating substance effected by the squirting method and that the effect of the mixture proportion on the temperature coefficient is due in particular to the thermic coefficient of expansion.

What is claimed is:

1. The method of producing magnetizable cores for inductance coils having a temperature coefficient of inductance of pre-given negative value and high constancy in time, comprising the steps of mixing a powdered ferromagnetic material

consisting of at least 50% of carbonyl iron powder with an insulating binder composed of polystyrol powder of normal molecular weight and polystyrol powder of a higher mean molecular weight, said powders being employed in a mutual proportion of weight designed for resulting in a temperature coefficient of pre-given negative value, and shaping said mixture by squirting.

2. A magnet core consisting of a squirted mixture of a ferromagnetic mass composed of 50 to 80% carbonyl iron powder and 50 to 20% powder of an iron-nickel alloy with about 78.5% nickel with an insulating binder containing polystyrol substances of different molecular weight, and characterized by a low negative temperature coefficient of inductance and high constancy in time of said coefficient.

3. A magnet core consisting of a squirted mixture consisting of a ferromagnetic mass composed

of carbonyl iron powder and a powdered iron-nickel alloy of high magnetic permeability, and of an insulating thermoplastic binder consisting substantially of polystyrol, said binder forming $\frac{1}{16}$ to $\frac{1}{8}$ in weight as compared with the weight of said ferromagnetic mass, and characterized by a low negative temperature coefficient of inductance and high constancy in time of said coefficient.

4. A magnet core consisting of a squirted mixture of ferromagnetic mass and an insulating binder, said ferromagnetic mass being composed of 50 to 80% carbonyl iron powder and 50 to 20% powder of an iron-nickel alloy with about 78.5% nickel, and said binder consisting of polystyrol and weighing $\frac{1}{16}$ to $\frac{1}{2}$ of the weight of said ferromagnetic mass.

PAUL GOTTSCHALT.