

2221575

Title: LAMINATED MAGNETIC CORE AND METHOD OF MANUFACTURING
SAME

FIELD OF THE INVENTION

This invention relates to a laminated magnetic core for a magnetic head, a transformer, or the like and a method of manufacturing such core.

BACKGROUND OF THE INVENTION

Previously, magnetic cores for magnetic heads, transformers and other similar devices have been manufactured by punching or stamping core chips each having a given shape with a punching press from a thin sheet (about 0.02 to 0.1 mm thick) of Permalloy, silicon steel or the like, magnetically annealing the chips, and laminating a given number of the chips while bonding them together with an organic adhesive. The reason why a number of chips each of a thin sheet are laminated in this way was to reduce eddy current loss and to thereby ensure favorable high-frequency characteristics.

Nevertheless, the conventional method has had the following shortcomings:

(1) With Permalloy that has been magnetically annealed (usually in hydrogen or a vacuum kept at 1000 to 1200°C for 1 to 4 hours), even a slight strain deteriorates its magnetic characteristics. The subsequent step of lamination is liable to strain the core chips partially because of the thinness of the core chips to be laminated together, thus seriously decreasing the yield of laminated magnetic core products .

(2) Laminating the punched core chips one by one requires

so much time and labor that it is a major obstacle to enhancement in productivity and cost reduction in the manufacture of magnetic heads and other products.

In order to overcome these shortcomings, the present inventor previously hit upon an idea of punching out core chips at a stroke from a stack of a given number of laminated thin sheets of Permalloy or the like and then magnetically annealing the resulting laminated core chip blocks. Specifically, the inventor proposed to preliminarily laminate core thin sheets with the use of an adhesive of sodium silicate (water glass) prior to punching operation. This method has proved effective but showed that it causes serious problems when the laminated magnetic cores are produced in a mass production as follows.

The sodium silicate adhesive, after drying following painting for the lamination of core-forming thin sheets, would become very hard and lose its elasticity. The bonded laminate stacks thus obtained, therefore, become weaker to bending stress. For this reason, a bonded laminate stack should be fed into a punching press to be used for punching core chips in the form of a limited length. This presented a press productivity problem in the case of mass production.

Thus, it is concluded that the above proposed method is not suitable to mass production which preliminarily laminate core-forming thin sheets with the use of an adhesive of sodium silicate prior to punching operation.

OBJECT OF THE INVENTION

From the view point of enhanced press productivity, the material to be press-worked must be fed from a coil of a

long, continuous strip which calls for a bonded laminate capable of withstanding the bending stress involved. In addition, the bonded laminate is required to stand the punching by a press, resist delamination after the magnetic annealing and exhibit excellent magnetic characteristics.

The present invention is aimed at the provision of a novel magnetic core article and its manufacturing method by which the above problems are eliminated.

SUMMARY OF THE INVENTION

After intensive research conducted in view of the foregoing, the present inventor has now created a laminated core production technique which attains increased bonding strength at the time of lamination, permits the feed in the form of a coiled laminate, permits to be satisfactorily punched out by a press, and undergoes no delamination after magnetic annealing.

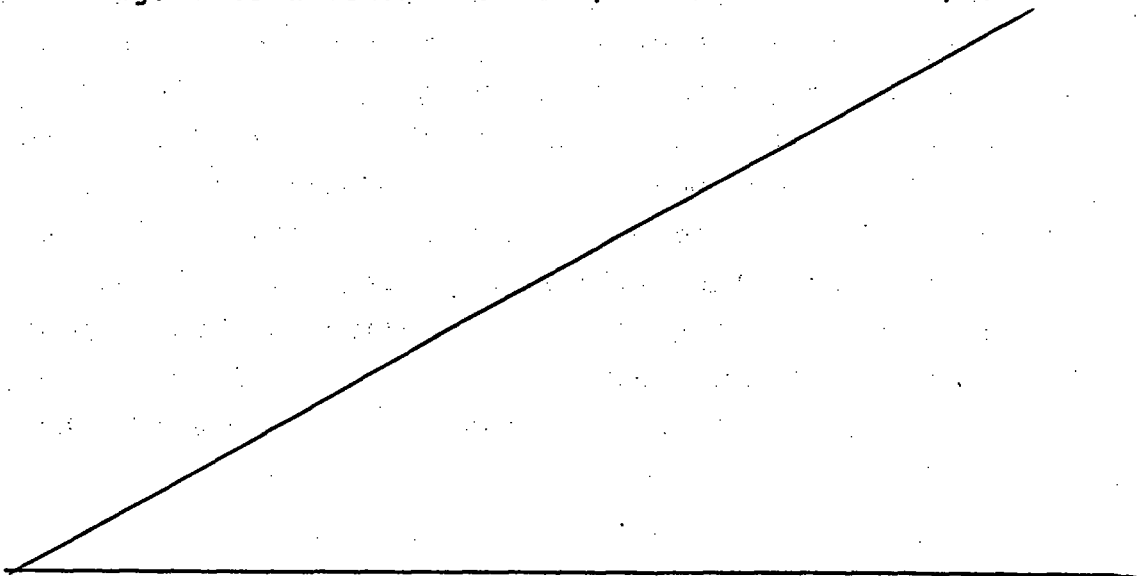
Thus, the present invention provides a laminated magnetic core comprising a stack of a plurality of core-forming sheets having a surface roughness such that the maximum height R_{max} is at least $1\mu m$, the distance between adjacent sheets being in the range of $2-10\mu m$, wherein each sheet has been bonded directly to the adjacent sheet or sheets by the use of an organic adhesive, which has subsequently been vaporized by heating to leave a multiplicity of gaps, between adjacent sheets, protruding portions of the roughened surfaces of adjacent sheets having been diffusion bonded directly to each other at their interface.

The present invention also provides a method of manufacturing a laminated magnetic core comprising the steps of providing a stack of a plurality of core-forming sheets having a surface roughness such that the maximum height R_{max} is at least $1\mu m$; bonding each core-forming sheet directly to the adjacent sheet or sheets by the use of an organic adhesive; punching out from the stack of core-forming sheets a block of a desired shape by means of a press; and magnetically annealing the stack of sheets of said block whilst decomposing and vaporizing the organic adhesive so as to leave a multiplicity of gaps and to effect diffusion-bonding at the interface between the roughened surfaces of adjacent sheets of the stack.

Preferably, the core-forming sheets are laminated with a sheet-to-sheet distance of 3 to $6\mu m$. The surface roughness may be adjusted such that the maximum height, R_{max} , is at least $1\mu m$ by use of a dull-finish roll.

BRIEF DESCRIPTION OF THE DRAWING

Fig. 1 is a schematic view, in cross section, of a



fragment of laminated thin sheet block before being magnetically annealed to form a laminated magnetic core in accordance with the present invention.

Fig. 2 is a schematic view, in cross section, of a fragment of laminated and diffusion-bonded thin sheet block after being magnetically annealed to form a laminated core in accordance with the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention will be better understood from the following detailed explanation.

First, in order to provide the resistance to bending stress and permit coiling of the laminated core-forming thin sheets, an organic adhesive for metal bonding as an adhesive at the time of laminating is used which exhibits a stronger adhesion. The organic adhesives for metal bonding employable is, for example, an epoxy resin, phenol resin, synthetic rubber, emulsion type polyvinylacetate, acrylic cyanoacrylate, or silicone rubber resin. Among them, the epoxy resin, synthetic rubber or acrylic cyanoacrylate is desirably used which is particularly excellent in the adhesion strength to metals and have better resistance to bending stress and press punching operation. However, such an organic adhesive has a shortcoming of inadequate heat resistance and decomposes on magnetic annealing, thereby causing delamination of the laminated core-forming thin sheets.

So, according to the present invention, the delamination after magnetic annealing is prevented by roughening the surface of the core-forming sheets with the use of dull-finish rolling, for example. Specifically, as illustrated in

Figs 1 and 2, when the core-forming sheets 1 each having a roughened surface are laminated through an adhesive 2, some of the protruded portions 3 on the roughened surfaces facing each other are caused to pass through the adhesive layer and come in contact with each other. When the magnetic annealing is effected, these contact portions of the protruded portions on the opposite roughened surfaces are firmly bonded through diffusion. The bonds 4 thus formed effectively prevents the delamination of the sheets even after the adhesive is vaporized off.

As the result, at the interface between adjacent core-forming sheets, innumerable voids are left which favorably maintain the insulation between the sheet layers.

This effects or advantages may be produced with a surface roughness having a maximum height, R_{max} , of at least $1\mu m$. The term " maximum height " is used herein according to the following definition: The maximum height, when a sampled portion has been interposed between the two parallel straight lines with a mean line of which length corresponds to the reference length that has been sampled from the profile shall be the value, expressed in micrometer(μm) measuring the spacing of these two straight lines in the direction of vertical magnification of the profile.

The upper limit of R_{max} is not specifically limited, but an R_{max} of $5\mu m$ or less is desirable, since an R_{max} exceeding $5\mu m$ makes it difficult to control the accuracy of thickness of a resulting laminate.

Core-forming sheets are laminated with a sheet-to-sheet distance in the range of 2 to $10\mu m$, preferably of 3 to $10\mu m$. Under the sheet-to-sheet distance of the above range, the

protruded portions on roughened surfaces facing each other are moderately and favorably bonded.

The core-forming sheet material to be used includes Permalloy, silicon steel, amorphous metal or the like.

This invention is illustrated by the following examples.

EXAMPLES

As magnetic head core material, PC Parmalloy (81% Ni-4% Mo-Fe) was used which had been used as a head core permalloy. It was subjected to final cold rolling to form thin sheets, 0.097 mm thick, with varied surface roughness values.

Next, six layers of each sheet were laminated through an epoxy adheshive for metal bonding. The total thickness of the laminate was controlled to be 0.6 mm $\pm$ 0.02 mm.

As comparative examples, six ply laminates of the same PC sheets were made using sodium silicate instead.

To determine whether these laminated sheets may be coiled or not, they were wound up around and set thereon a spool having 500 mm diameter. The sheets laminated through the epoxy resin adheshive in accordance with the present invention were allowed to stand at room temperature and the laminated sheets of the comparative examples were allowed to stand at 85 °C, each for a time period of 24 hours. The laminated sheets were then fed to a press for punching core chip blocks of a given shape therefrom. The laminated sheets of the comparative examples made by the use of sodium silicate could not endure the bending stress imposed and were delaminated (when the laminated sheets dried and set around and on the spool is fed to a press, they were subjected to a

stress, since they are forcibly flattened.).

The laminated sheets that used the epoxy adhesive in accordance with this invention did not present the delamination and core chip blocks could be punched out therefrom.

Next, laminated blocks thus punched by a press were degreased with acetone and magnetically annealed in hydrogen at 1100 °C for 4 hours.

Following the magnetic annealing the laminated blocks were inspected as to whether delamination is occurred and the laminated blocks free from delamination were incorporated into a magnetic head and tested for their magnetic characteristics. The results are given in Table 1.

Table 1

Example No.	Rmax μ m	Delamination	Impedance (80 kHz)
This invention:			
1	1.5	No	28 k Ω
2	2.3	No	27 k Ω
3	3.7	No	27 k Ω
Comparative:			
4	0.8	Yes	- -
5	Conventional Process (laminated after annealing)		30 k Ω

As can be seen from Table 1, Examples according to this invention underwent no lamination after magnetic annealing. Their magnetic characteristics which were evaluated as impedance at 80 kHz pose no problem for practical purposes, although their values were only slightly lower than that of one according to conventional process. The reason of the slight inferiority is that the layer-to-layer insulation is somewhat worsened due to the presence of contacted and bonded portions formed by diffusion at the interface between the layers.

Advantages of the invention

This invention has excellent advantages that greatly enhances the productivity in the manufacture of laminated cores for magnetic heads, transformers and the like without lowering their magnetic characteristics. With this excellent

advantages this invention is expected to contribute largely to the further progress in the field of electronic devices and components.



C106/N

CLAIMS

1. A laminated magnetic core comprising a stack of a plurality of core-forming sheets having a surface roughness such that the maximum height R_{max} is at least $1\mu m$, the distance between adjacent sheets being in the range of $2-10\mu m$, wherein each sheet has been bonded directly to the adjacent sheet or sheets by the use of an organic adhesive, which has subsequently been vaporized by heating to leave a multiplicity of gaps, between adjacent sheets, protruding portions of the roughened surfaces of adjacent sheets having been diffusion bonded directly to each other at their interface.
2. A laminated magnetic core as claimed in claim 1 wherein the distance between adjacent sheets is in the range $3 - 6 \mu m$.
3. A laminated magnetic core substantially as herein described with reference to the accompanying drawings.
4. A method of manufacturing a laminated magnetic core, comprising the steps of providing a stack of a plurality of core-forming sheets having a surface roughness such that the maximum height R_{max} is at least $1\mu m$ bonding each core-forming sheet directly to the adjacent sheet or sheets by the use of an organic adhesive; punching out from the stack of core-forming sheets a block of a desired shape by means of a press; and magnetically annealing the stack of sheets of said block whilst decomposing and vaporizing the organic adhesive so as to leave a



- 12 -

multiplicity of gaps and to effect diffusion-bonding at the interface between the roughened surfaces of adjacent sheets of the stack.

5. A method as claimed in claim 4, wherein the core-forming sheets are bonded to one another with a distance between adjacent sheets in the range of 2 - 10um.

6. A method as claimed in claim 5, wherein the distance between adjacent sheets is in the range of 3 - 6um.

7. A method as claimed in any one of claims 4 - 8, wherein the surface roughness of the core-forming sheets is adjusted using a dull-finish roll.

8. A method of manufacturing a laminated magnetic core, substantially as herein described.

9. A laminated magnetic core manufactured by the method of any one of claims 4 - 8.
