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BONDED MAGNETIC CORE AND PROCESS FOR PRODUCING IT

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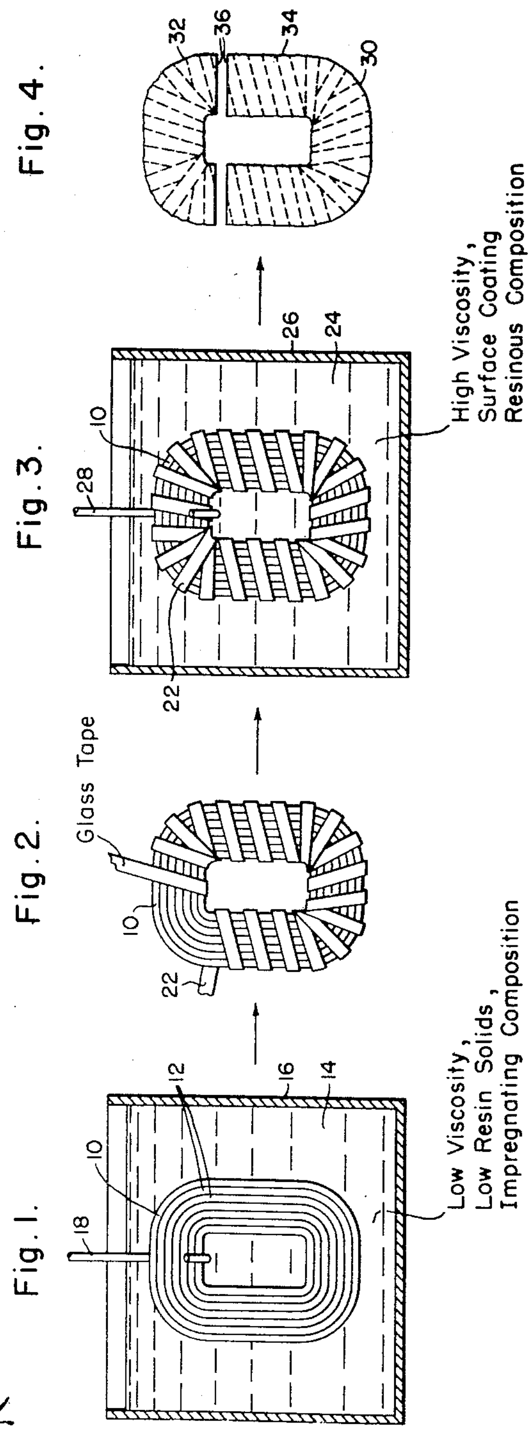

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BONDED MAGNETIC CORE AND PROCESS FOR PRODUCING IT

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This invention relates to bonded magnetic cores and the processes by which they may be produced.

In the electrical industry there are being produced a substantial number of bonded magnetic cores. In many cases these cores comprise assembled laminated magnetic material, ordinarily preferentially oriented magnetic material, and the assembled laminations are bonded with suitable resinous binders and finally the bonded magnetic cores are cut into sections that may be assembled in association with electrical coils. The manufacturing operations of cutting the bonded magnetic core often result in splitting or delamination of the magnetic core and the core is then not usable and is scrapped or reprocessed. In the handling and assembling of the cut bonded magnetic core sections, the cores may split or delaminate, and even in service cores will occasionally separate and result in unsatisfactory operation. In any event, a split or delaminated magnetic core constitutes a loss.

The bonding of laminations together to produce the best bonded cores so that splitting or delamination does not take place to a marked extent, may be obtained if the interlaminar spaces are completely filled with a good resin binder. However, the electrical losses in resin bonded magnetic cores have been found to be a function of the type of resinous binder used and the amount of the resin binder present. Therefore, if the interlaminar spaces are completely filled with a given resin, the core losses in an alternating current field will be the highest whereas if the interlaminar spaces are only partly filled, the core losses will be proportionately less. The minimum core losses for a given core are obtained when no resin is present. There is evidence that, because the interlaminar spaces are so thin, when filled with a resin and cured in such thin sections to function as a binder for the laminations, the applied thin sections of resin shrink and develop physical distortions of such magnitude that they impose strains on the magnetic laminations. The magnetic laminations, particularly if preferentially oriented, are extremely sensitive to strains. Therefore, even with the best core binders available today, core losses may be substantial.

It accordingly will be apparent that in the building of magnetic cores the use of large amounts of resin binder so as to fill the interlaminar spaces will reduce the splitting and delamination of cores during subsequent manufacturing and service use, but large amounts of

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resin tend to increase the core losses. This requires the manufacturing and design engineers to make a compromise between excessive scrapping of cores due to splitting and delamination, and high electrical core losses. Furthermore, even with the best practice, the normal non-uniformities in impregnation, cutting and other steps of the manufacturing processes result in the production of a substantial amount of scrap due to delamination and split cores. It has been a problem in the manufacture of electrical cores to reduce such scrap to a low proportion of the total number of cores manufactured.

The object of this invention is to provide for a process for bonding laminations of a magnetic core by, first, applying a relatively small quantity of resin binder to effect interlaminar bonding through spots of adhesive and then applying a wrapping of a fibrous material in combination with a heavy coating of resin to the exterior of the core to provide for both good bonding and low core losses.

Another object of this invention is to provide for a bonded laminated magnetic core in which the bonding means is applied mainly to the exterior of the core and only a minor proportion of binder is applied to the interlaminar spaces within the core.

Other objects of the invention will in part be obvious and will in part appear hereinafter. For a better understanding of the nature and object of the invention reference should be had to the following detailed description and drawing, in which:

Figure 1 is a vertical cross section,

Fig. 2 is a view in elevation of a magnetic core,

Fig. 3 is another vertical cross section, and

Fig. 4 is a view in elevation of a completed magnetic core comprising two sections.

I have discovered that bonded laminated magnetic cores having extremely low core losses, approaching those of the unbonded magnetic cores may be held together by bonding means applied mainly to the exterior of the core and associated with a predetermined small amount of interlaminar resin binder so that they will withstand manufacturing and service use with negligible delaminating and splitting. Briefly, the process for preparing the cores comprises the following steps: first, the assembled laminations of magnetic material are treated to apply to the interlaminar spaces a bonding resin which when cured fills less than 18% of the interlaminar spaces; then, after curing the resinous interlaminar binder, the exterior of the magnetic core, except for working faces, is wrapped to cover at least a major portion thereof with a non-conductive, fibrous wrapping; and, finally, the exterior of the core, except for the working faces, is heavily coated with a bonding resin that penetrates the fibrous wrapping. By this process I have produced magnetic cores whose electrical losses are very nearly the same as the losses of the original uncut core. The scrap losses in manufacturing and service operations are substantially completely eliminated.

The four figures of the drawing illustrate consecutive steps followed in the practice of the process of this invention. Referring to Fig. 1 of the drawing, there is illustrated the first step in which the magnetic core 10 comprising a plurality of assembled laminations 12, which core has been annealed to remove strains developed during its manufacture and assembly, is immersed in a low viscosity, low resin solids impregnating composition 14 maintained within a receptacle 16. The magnetic core may be suspended from a support 18 or the magnetic core may be simply stacked within the receptacle 16 and the impregnating composition 14 flowed over the cores and then withdrawn as is well known in impregnating procedures. The impregnating composition 14 preferably comprises less than 18% of curable resin solids, the balance being volatile solvent. The impregnating composition may have as little as 5% curable resin solids. When immersed, composition 14 will penetrate readily into the interlaminar spaces between the laminations 12. Since the interlaminar spaces are ordinarily less than 1 mil in thickness, the impregnating composition 14 will be retained therein by capillary forces. The core 10 may be withdrawn from the impregnating composition 14 and is heat treated to drive off the solvent and to cure the resin in order to bond the laminations 12 to one another. The quantity of cured resin present between laminations will be less than 18% of the interlaminar spaces.

I have discovered that when the quantity of applied resin is less than 18%, the alternating current losses induced by any strains that may be imparted by the cured resin in the interlaminar spaces are extremely low. When cores so prepared are split apart, it is found that the resin gives spot adhesion and does not bond substantial areas of laminations to one another. This type of spot adhesion appears to favor low electrical core losses.

Numerous types of resins may be employed for providing this interlaminar bonding. A thermosetting resin will ordinarily be preferred even though it may cause a slightly greater electrical loss than would a thermoplastic resinous binder. A thermoset binder enables cores to be employed at higher operating temperatures than is permissible with thermoplastic materials. Furthermore, resistance to hot oil or other dielectric is superior with thermoset binders. Resinous binders giving the lowest electrical losses are selected for the interlaminar impregnation.

After the impregnated core has been heat treated to cure the small amount of applied impregnating resin in the interlaminar spaces, its exterior is then tightly wrapped with a nonconducting fibrous material. The fibrous material may be composed of glass fiber tape, glass fiber cord, strands of glass fiber, cotton cord asbestos tape or tapes of synthetic resin fibers, for example glycol-terephthalate fibrous polymers and nylon. The applied fibrous wrapping should cover at least half of the exterior surface of the magnetic core or it may be applied to substantially completely cover the entire exterior surface of the core, except for core faces that may be present in some types of cores. It is preferable that the applied fibrous wrapping be relatively open in structure in order that the next step in the process be more effective. As shown in Fig. 2, a glass tape 22 is applied as a fibrous wrapping to the heat treated magnetic core 10.

Referring to Fig. 3 of the drawings, the magnetic core 10 with the glass wrapping 22 is immersed in a high viscosity, surface coating resinous composition 24 disposed within a tank 26. The magnetic core may be suspended by a support 28 or introduced by any suitable means into the tank 26. The resinous coating composition 24 contains a curable resinous composition present in such amount and of such viscosity that it will not substantially penetrate into the interlaminar spaces of the core 10. However, the resinous composition will penetrate into the open textured fibrous wrapping 22 and will heavily coat all of the exterior surfaces of the magnetic core 10 so that when the core 10 is withdrawn from the tank 26 a substantial thickness of the composition will be present on all surfaces of the magnetic core. The core 10 is then heated or otherwise treated to cause the coating composition 24 present on all of the exterior surfaces to cure into a hard bonding coating. The combination of the interlaminar binder and the fibrous wrapping and the applied cured composition 24 produces a bonded core that will withstand all reasonable manufacturing and service conditions.

The fully bonded magnetic core may be readily machined, ground and etched as required to produce sectioned magnetic cores having working faces. As illustrated in Fig. 4 of the drawing the magnetic core 10 with the exterior coating 30 of cured resin composition and glass tape has been cut into two sections 32 and 34 having machined faces 36 that will fit closely together.

Examples of the practice of the present invention are the following:

Example I

A number of magnetic cores of a size to be employed in 3 kv.-a. 7200 volt transformers were prepared by winding 14 mil thick strips of preferentially oriented silicon iron. The cores when wound were in the form of looped cores such as is shown in the figures of the drawing. After strain anneal, these cores were then immersed in an impregnating resinous composition comprising 85% solvents (a mixture of acetone and alcohol) and 15% of curable resin solids. The resin solids comprised a mixture of (*a*) 100 parts by weight of polyvinyl acetate and (*b*) 70 parts by weight of the potentially reactive, partial reaction product of aniline, phenol and formaldehyde reacted in the proportions 160 parts of aniline, 533 parts of phenol, 200 parts of paraformaldehyde and 110 parts by weight of 40% formaldehyde. After the cores were impregnated in the composition, they were then baked for 2 hours at 200° C. to drive off the solvent and to cure the resin in the interlaminar spaces. The baked cores were then wrapped with an open weave glass tape 1 inch in width in which the turns of the wrapping were spaced approximately ¼" apart at the outside of the looped core. The wrapped cores were then immersed in a high viscosity resinous epoxide having 70%

resin solids. The viscosity of the resinous epoxide composition was over 1000 centipoises. It formed a heavy coating and impregnated into the open weave glass cloth without penetrating appreciably into the interlaminar spaces. The cores were then cured by heating at a temperature of 100° C. for 1 hour. However, this epoxide resin could be modified by the addition of a higher proportion of an amine catalyst so that it would cure at room temperature in 6 hours. Thereafter the completed core was cut into two sections as required for making of a transformer therewith, and was tested for electrical losses. The average true watts per pound of magnetic core, after winding but before any impregnation, was 0.689. After the process of impregnation, bonding and cutting was completed, the average true watts per pound value was 0.701. This change in loss is less than 2%. Of the entire series of cores prepared, none delaminated or split and all exhibited excellent physical and electrical properties.

Example II

Another series of wound magnetic cores of the shape shown in the figures of the drawing was prepared by impregnating the interlaminar spaces with a resinous composition comprising 15% of curable resin solids and 85% of solvent. The resin solids comprised 67 parts by weight of a potentially reactive resorcinol formaldehyde resin disclosed in Example II of Patent 2,542,048, and 200 parts of polyvinyl acetate of medium molecular weight. After curing the applied resin composition, the magnetic cores were all wrapped with open weave glass tape in the manner set forth in the preceding example. The cores were then dipped in a similar epoxide resin to that used in Example I. After the curing of the applied epoxide resin, the wound cores were each split into two U-shaped sections and the faces were ground and etched. The magnetic cores were then tested for electrical losses. In this series of cores, the average true watts per pound was 0.687 before the cores were impregnated, while after the entire bonding and cutting process of this invention, the average true watts per pound was 0.665. This is a reduction in losses of approximately 3%.

The resinous epoxide composition employed in the examples was prepared as follows.

Four moles of 4,4′-dihydroxy diphenyl-2,2-propane and five moles of epichlorhydrin were added to an aqueous caustic soda solution containing 6.43 moles of sodium hydroxide. The reaction mixture was heated slowly from an initial temperature of 40° C. to 100° C. in 80 minutes. Reaction was continued for one hour at a temperature of from 100° C. to 104° C. The reaction mixture was then permitted to stand until it separated into two layers. An upper aqueous layer was drawn off and discarded. The lower layer containing the resinous reaction product was first washed with water several times and the water withdrawn to remove excess caustic. Dilute acetic acid was then stirred in to neutralize unreacted caustic. Further washing in water was carried out until the wash water was neutral to litmus. The product was freed from water by decantation and then heated to 130° C. to eliminate all traces of water. The resinous product so formed had a softening point of 100° C. using Durran's mercury method.

The resinous epoxide so prepared was dissolved in a solvent, such as acetone, methyl ethyl ketone or ethyl acetate, or a mixture of solvents, to produce the solution of surface coating resinous composition. The resin may be catalyzed by adding a small amount (0.1% to 4%) of an aliphatic amine, such as diethyl amine, or an alkali such as potassium hydroxide or sodium phenoxide.

Numerous other resins may be employed both for the impregnating composition and for the surface coating resinous composition of high viscosity as disclosed herein. Thus the magnetic core may be initially impregnated with a low viscosity solution prepared in accordance with my Patent 2,372,074. The surface coating resinous composition may include high viscosity, heat hardening resinous compositions such as melamine-formaldehyde resins, aniline-phenol formaldehyde resins combined with thermoplastic additives, and resorcinol-formaldehyde resin with vinyl polymers added thereto as disclosed in Nagel Patent 2,542,048. Again, both the impregnating composition and the surface coating composition may be a polysiloxane resin. Thus the impregnating composition may be a heat hardening low viscosity, low solids content phenyl methyl siloxane and the surface coating composition may be a heat hardening, high viscosity phenyl methyl siloxane or other polysiloxane resin.

While the drawing has been illustrated with reference to a looped wound core comprising a plurality of turns of magnetic material, the invention may be applied to other magnetic core structures either of parallelepiped form or of other shape. The magnetic cores may comprise not only sheets of magnetic material but ribbon, wire or other shaped magnetic material that may be assembled into a magnetic core.

Regardless of the shape or size of the magnetic core the processes disclosed herein will enable the strongest bonded magnetic core with lowest electrical losses of any produced heretofore.

Since certain changes may be made in the above invention and different embodiments of the invention may be made without departing from the scope thereof, it is intended that all matter contained in the above disclosure shall be interpreted as illustrative and not in a limiting sense.

I claim as my invention:

1. In the process of producing a bonded laminated magnetic core, the steps comprising assembling laminations of magnetic material to form a core, impregnating the spaces between the laminations of the assembled core with a low viscosity penetrating solution of a resin, the solution having a curable resin solids content of less than 18% by weight and the balance of the solution being solvent, heat-treating the impregnated core to drive off the solvent and to cure the applied resin to bond the laminations to one another, the amount of applied cured resin being insufficient to bond the laminations into a core capable of withstanding subsequent manufacturing and service use, wrapping a substantial portion of the exterior of the heat-treated core with nonconducting fibrous material, applying a viscous and substantially non-penetrating curable resinous composition to the wrapped laminated core to coat the exterior surface of the core without penetrating the interlaminar spaces and to coat the fibrous wrapping material, and curing the last-mentioned applied resinous composition, the laminations of the resulting magnetic core being so well bonded that the core will

withstand manufacturing and service use and the quantity of resin between laminations being so low as to cause low magnetic losses in service.

2. In the process of producing a wound magnetic core, the steps comprising winding sheet magnetic material into a looped magnetic core having a plurality of turns, impregnating the interlaminar spaces between turns of the wound core with a low-viscosity penetrating solution of a resin, the solution having a curable resin solids content of less than 18% by weight and the balance being solvent, heat-treating the impregnated core to drive off the solvent and to cure the applied resin to bond the turns to one another, the amount of the applied cured resin being insufficient to bond the turns into a looped core capable of being cut and withstanding subsequent manufacturing and service use, wrapping a substantial portion of the exterior surface of the looped core with a non-conducting fibrous material, applying a viscous and substantially non-penetrating resinous curable composition to the wrapped looped core to coat all the exterior surface of the core without penetrating the inerlaminar spaces between turns and to coat the fibrous wrapping material, curing the last-mentioned applied resinous composition, cutting the resulting wound core to produce two U-shaped sections, the combined resins and wrapping material providing a wound core that may be cut and further processed to produce apparatus without delaminating and characterized by low magnetic losses.

3. A bonded, integral magnetic core comprising a plurality of assembled laminations of magnetic material, resinous bonding material applied between laminations, the resinous bonding material filling less than 18% of the interlaminar spaces,

a non-conducting fibrous material wrapped about a major proportion of the exterior surface of the magnetic core, a relatively heavy coating of resin applied to the exterior surface, the fibrous wrapping material and the heavy coating of resin applied to the exterior of the core providing for bonding the laminations into an integral core.

4. A bonded, integral magnetic core section having a plurality of assembled laminations with at least one working face, resinous bonding material applied between laminations, the resinous bonding material filling less than 18% of the interlaminar spaces, a non-conducting fibrous material wrapped about a major proportion of the exterior surface of the core section except for the working faces, a relatively heavy coating of resin applied to all of the exterior surface of the core section, except the working faces, and to the fibrous wrapping material, the fibrous wrapping material and the heavy coating of resin applied to the exterior of the core section providing for bonding the laminations into the integral section capable of withstanding manufacturing and service use without delamination.

5. The core section of claim 4 wherein the fibrous wrapping material consists of glass fibers.

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