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(54) Ignition coil.

(57) An ignition coil for developing a spark plug firing voltage. The ignition coil is comprised of first and second parts (12,14) that are formed of iron particles in a binder of electrical insulating material which define axially spaced end wall portions (12D,14D). The parts are connected by a core member (16) that is formed of magnetic material. A primary winding (18) is disposed about the core member and a secondary winding (22) is disposed about the primary winding. An axially extending part (12B,14B) that is formed of magnetic material is located outside of the secondary winding and magnetically connects the end wall portions.

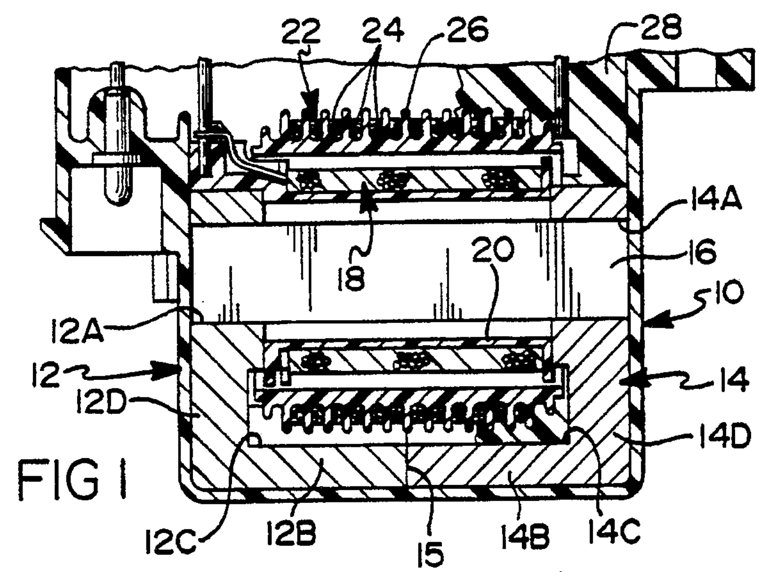

FIG I

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IGNITION COIL

This invention relates to ignition coils and more particularly to ignition coils where the magnetic circuit for the ignition coil is comprised of magnetic parts that are comprised of powdered iron particles that are coated with an electrical insulating material that forms a binder for the iron particles and which also electrically insulates the iron particles from each other to form insulating gaps between the iron particles.

Ignition coils frequently utilize laminated steel material as the magnetic circuit for the primary and secondary windings. An example of this is disclosed in the US patent no. 4,480,377. There are disadvantages to using steel lamination stacks. Thus, the use of steel lamination causes size and shape restrictions in the packaging of the design. Further, potting materials for ignition coils are not compatible with sheet electrical steel. Thus, if potting material is applied to laminated stacks, stress cracks are produced at the sharp edges of the steel sheets. Another problem associated with laminated stacks is that the magnetic circuit needs air gaps which must be precisely adjusted during the manufacture of the ignition coil. This adjustment of the air gaps is explained in the above-referenced US patent.

An ignition coil in accordance with the present invention comprises core means which extends axially and which is formed of magnetic material; a primary winding disposed about the core means; a secondary winding disposed about the primary winding; end wall portions formed of iron particles in a binder of electrical insulating material, the electrical insulating material being interposed between the iron particles to form a plurality of gaps between the iron particles that operate like air gaps, the end wall portions being axially spaced and connected by the core means; and axially extending means formed of magnetic material, located outside of the secondary winding, and magnetically connecting the end wall portions, the axially extending means extending only part way about the secondary winding in the circumferential direction.

It, accordingly, is an object of this invention to provide an ignition coil where parts of the magnetic circuit of the ignition coil are formed of iron particles that are insulated from each other by an electrical insulating material and where the electrical insulating material binds the iron particles together. Use of parts formed of iron particles and electrical insulating material eliminates the design and manufacturing problems associated with steel laminations. Thus, the magnetic parts are compatible with potting material. Further, the composite iron particles and electrical insulating material can be moulded into various shapes. In addition, by utilizing the composite iron particles and electrical insulating material, no air gap need be provided in the magnetic circuit that would require adjustment. Thus, the air gap is distributed throughout the magnetic circuit because individual particles of powdered iron are coated with electrical insulation. Putting it another way, the composite material has many small gaps distributed throughout the material that act like air gaps.

US patent no. 2,885,458 discloses an ignition coil where an annular or toroidal core is formed of an iron powder and a binder, such as phenolic which is moulded to shape. This arrangement differs from the present invention, in that among other things, the magnetic circuit is comprised of at least two parts that are arranged to facilitate assembly of the primary and secondary windings of the ignition coil.

The present invention will now be described, by way of example, with reference to the following description, and the accompanying drawings, in which:-

Figure 1 is a sectional view of an ignition coil made in accordance with this invention;

Figure 2 is an end view of a component of the ignition coil shown in Figure 1;

Figures 3 illustrates a magnetic part that can be used in place of certain of the magnetic parts shown in Figure 1;

Figure 4 is a sectional view taken along line 4-4 of Figure 3;

Figure 5 is a sectional view taken along line 5-5 of Figure 4; and

Figure 6 illustrates a modified magnetic circuit for the ignition coil of Figure 1.

Referring now to the drawings and more particularly to Figure 1, the reference numeral 10 designates a (generally cup-shaped) case that is formed of a moulded plastic insulating material. Disposed within the case 10 are two (generally L-shaped) magnetic parts 12 and 14 that form part of the magnetic circuit for the ignition coil. These magnetic parts 12 and 14 are formed of a composite iron powder and electrical insulating material which is compression moulded to the shape shown in the drawings. This composite material will be described in greater detail hereinafter. The magnetic parts 12 and 14 are identical and one of these magnetic parts is shown in greater detail in Figure 2. For purposes of description, it will be assumed that magnetic part 14 is shown in Figure 2. The magnetic part 14 has a rectangular hole 14A, an axially extending portion 14B that has an circular inner surface 14C and a radially extending end wall portion 14D. Corresponding portions of magnetic part 12 have been designated as 12A, 12B, 12C and 12D. The end faces of axially extending portions 12B and 14B are engaged along line 15 to define axially extending means. This engagement is maintained by press fitting magnetic parts 12 and 14 between inner opposed surfaces of case 10.

The ignition coil has a core member 16 that is formed of magnetic material. The core member 16 is rectangular in cross-section to match rectangular holes 12A and 14A. The core member 16 is inserted into rectangular holes 12A and 14A during assembly of the ignition coil and may have a press-fit with the rectangular holes. In the final assembled position of core member 16, the opposite ends thereof are located respectively in rectangular holes 12A and 14A. The core member 16 magnetically connects magnetic parts 12 and 14 and it also serves as a core or core means for primary and secondary windings 18,22 of the ignition coil.

The core member 16 can be formed from a stack of steel laminations, that is, a plurality of steel laminations. Alternatively, core member 16 could be a solid iron rod or bar. Further, core member 16 could be formed of the same material as magnetic parts 12 and 14, that is, a moulded composite iron powder particles and electrical insulating material.

The primary winding of the ignition coil is designated as 18. It is comprised of a number of turns of wire that are wound on and supported by a spool 20 that is formed by insulating material. The spool 20 and primary winding 18 are disposed about core member 16.

The secondary winding of the ignition coil is generally designated as 22. The secondary winding 22 is a so-called segment-wound winding since it has a plurality of series-connected winding portions or sections 24 that are wound into annular grooves formed in a spool 26. Twelve individual winding sections are shown in Figure 1. The spool 26 is formed from an electrical insulating material.

To assemble the ignition coil that has been described, one end of core member 16 can be inserted into, for example, the rectangular hole 12A in magnetic part 12. A primary winding unit comprised of spool 20 and primary winding 18 carried thereby is now assembled over core member 16. Following this a secondary winding unit comprised of spool 26 and the secondary winding 22 carried thereby is assembled over the primary winding unit. The magnetic part 14 is now assembled such that the end of core member 16 is inserted into rectangular hole 14A and such that end surfaces of axially extending portions 12B and 14B are in contact.

When the various parts have been assembled as described, they are placed in case 10 and are then encapsulated by a potting compound formed of insulating material that is designated as 28. This potting compound 28 closes the open end of case 10. The potting compound 28 secures the various parts of the ignition coil together and bonds to the case 10 to retain the various parts of the ignition coil in case 10. Putting it another way, the potting compound 28 fills open spaces in and around the various parts of the ignition coil.

Figures 3-5 illustrate a magnetic part 30 that may be substituted for the magnetic parts 12 and 14 of the ignition coil shown in Figure 1. The magnetic part 30 is formed of magnetic material of the same type that is used for magnetic parts 12 and 14, that is, a moulded composite iron powder particles and electrical insulating material. Magnetic part 30 has end wall portions 30A and 30B joined by axially extending portion 30C. End wall portions 30A and 30B, respectively, have (open-ended radially extending) slots 30D and 30E. The slots 30D and 30E receive the ends of a core member, like core member 16 which is press fitted to the slots. It will be appreciated that axially extending portion 30C performs the same function as axially extending portions 12B and 14B of the arrangement shown in Figure 1, and hence defines axially extending means.

Figure 6 illustrates another modified magnetic circuit. In Figure 6, magnetic parts 32 and 34 are substituted for magnetic parts 12, 14 and core member 16 of Figure 1. Primary and secondary windings 18 and 22 are shown diagrammatically and would have spools like the ones shown in Figure 1. Magnetic parts 32 and 34 are formed of the same type of magnetic material as magnetic parts 12 and 14, that is, a composite iron powder particles and electrical insulating material. Magnetic part 32 has an axially extending portion 32A, the end face of which abuts or engages the end face of axially extending portion 34A of part 34. Axially extending portions 32A and 34A correspond to axially extending portions 12B and 14B of Figure 1 and have the same shape as these parts, and hence define axially extending means. In Figure 6, the core for primary winding 18 and secondary winding 22, rather than being a separate part, is formed by engaged axially extending portions 32B and 34B of magnetic parts 32 and 34. Axially extending portions 32B and 34B are integral with and extend axially from end wall portions 32C and 34C of magnetic parts 32 and 34. Axially extending portions 32B and 34B can be square in cross-section like core member 16 or could have a circular cross-section.

As previously described, magnetic parts 12, 14, 16, 30, 32 and 34 can all be formed of a composite magnetic material, that is, particles of powdered iron in a binder formed of electrical insulating material. The final compression moulded product should be such that individual iron particles are coated by the electrical insulating material. The insulating material then forms two functions, namely, it insulates iron particles from each other and it binds the iron particles together. The electrical insulating coating on and between iron particles act like many small air gaps distributed throughout the composite material. The gaps, of course, are not actually formed of air, but since insulating material has about the same permeability as air, an air gap effect is achieved.

This invention is not restricted to the type of iron particle powder that is used nor to the type of particle insulation that is used. The mean particle size of the iron particles may be about 0.1mm (0.004 inches). One example of an iron powder is a Hoeganeas Corp. 1000B powder. This iron powder can be mixed with a suitable epoxy resin powder and the mixture is then compacted in a press or mould to the desired shape. The shaped part is then cured and the resultant product is a material where the iron particles are insulated from each other by the epoxy insulating material which also serves to bind the iron particles together. The final product may have a range of about 0.5 to 2% by weight of epoxy material with the remainder being iron particles.

The composite material may be comprised of iron particles which are bound together and separated by a cured thermoplastic material. Thus, iron particles of a mean particle size of about 0.1mm (0.004 inches) can be coated with a thermoplastic material. The coated particles are placed in a heated mould and then compression moulded to the desired shape and density. The final product is a composite part that is comprised of cured thermoplastic material and iron particles. The cured thermoplastic materials binds the iron particles together and serves to insulate a majority of the iron particles from each other. However, it is possible that some of the iron particles will become engaged during moulding pressure but the final product has a multiplicity of gaps that act like air gaps. The final moulded part, by volume, may be about 96% iron particles and about 4% thermoplastic material.

In a conventional ignition coil design utilizing sheet metal laminations, the density of the sheet steel is a constant value. Therefore, the amount of iron designed into the circuit (to prevent saturation of the circuit with flux density) is controlled by the cross sectional area and stacking factor of the lamina. Also, the steel sheet is continuous, therefore, the air gap designed into the circuit (to control the primary inductance needed to provide the desired energy storage) is controlled by the amount that is physically cut out of the circuit. In an ignition coil design utilizing electrically insulated iron particles, the density of the powdered metal form is variable. Therefore, the amount of iron designed into the circuit is controlled by the cross sectional area and the density attained by the powdered metal compaction process. Also, the powdered iron particles are insulated from each other by the electrical insulating coating, therefore, the air gap designed into the circuit is controlled by the number of coated powdered iron particles present in the powdered metal form and the space between them. The number of coated iron particles present and the spacing between them are determined by the length of the flux path designed in the form, the cross sectional area, and the density attained by the powdered metal compaction process.

There is a relationship between the amount of iron and air gap present with respect to the flux density generated in the powdered metal form. This relationship can be explained as follows. For a given ignition coil design, utilizing a known powdered metal material quantity, the quantity of iron and amount of air gap needed to provide the desired ignition coil performance can be determined. Then, to develop the size and shape of the magnetic circuit, the cross sectional area must be made optimum. If there is not enough cross sectional area, the flux density will be too high and saturate the iron. The iron saturation will cause poor performance due to low energy transfer efficiency and high core losses. If there is too much cross sectional area, the flux density will be too low and the lines of flux will bypass the air gaps. The number of gaps present may have been sufficient to provide enough stored energy, but they were not all utilized in the magnetic circuit. Therefore, there will still be an apparent saturation of the iron and a poor performance due to low energy transfer efficiency and high core losses.

Therefore, when there is too much iron in the magnetic circuit because of too much cross sectional area, even though the cumulative air gap caused by the iron particle coatings and the spacing between the iron particles is correct with respect to the ignition coil design, the lines of flux are selective and only utilize a portion of the air gaps. This results in an undesirable situation. If the situation is over corrected by reducing the cross sectional area too much, the iron becomes saturated. This results in an undesirable situation. The point where the iron is being fully utilized but not saturated, and the air gaps are being fully utilized but not saturated is the design window desired for the most efficient ignition coil design utilizing electrical insulated powdered metal particles for the magnetic circuit.

To achieve optimum results, the magnetic circuit is designed in a manner that has been described with due regard to the electrical performance to be achieved by a given ignition coil design.

Attention is drawn to our patent application no. (MJD/3335), filed the same day as the present application.

Claims

1. An ignition coil comprising core means (16) which extends axially and which is formed of magnetic material; a primary winding (18) disposed about the core means; and a secondary winding (22) disposed about the primary winding; characterised by end wall portions (12D,14D) formed of iron particles in a binder of electrical insulating material, the electrical insulating material being interposed between the iron particles to form a plurality of gaps between the iron particles that operate like air gaps, the end wall portions being axially spaced and connected by the core means; and by axially extending means (12B,14B) formed of magnetic material, located outside of the secondary winding, and magnetically connecting the end wall portions, the axially extending means extending only part way about the secondary winding in the circumferential direction.
2. An ignition coil according to claim 1, wherein the core means (16) is comprised of a plurality of steel laminations.
3. An ignition coil according to claim 1, wherein the core means is an iron rod.
4. An ignition coil according to claim 1, wherein the core means (32B,34B) is comprised of the same material as the end wall portions (32C,34C).
5. An ignition coil according to claim 1, wherein the core means is comprised of engaged axially extehding portions (32B,34B) of the end wall portions (32C,34C).
6. An ignition coil according to any one of claims 1 to 5, wherein the axially extending means that is located outside of the secondary winding (22) is comprised of axially extending engaged portions (12B,14B,32A,34A) of the end wall portions (12D,14D,32C,34C).
7. An ignition coil according to any one of claims 1 to 5, wherein the axially extending means that is located outside of the secondary winding (22) is comprised of an axially extending length (30C) of material that is of the same type as the material of the end wall portions (30A,30B) and which is integral therewith.

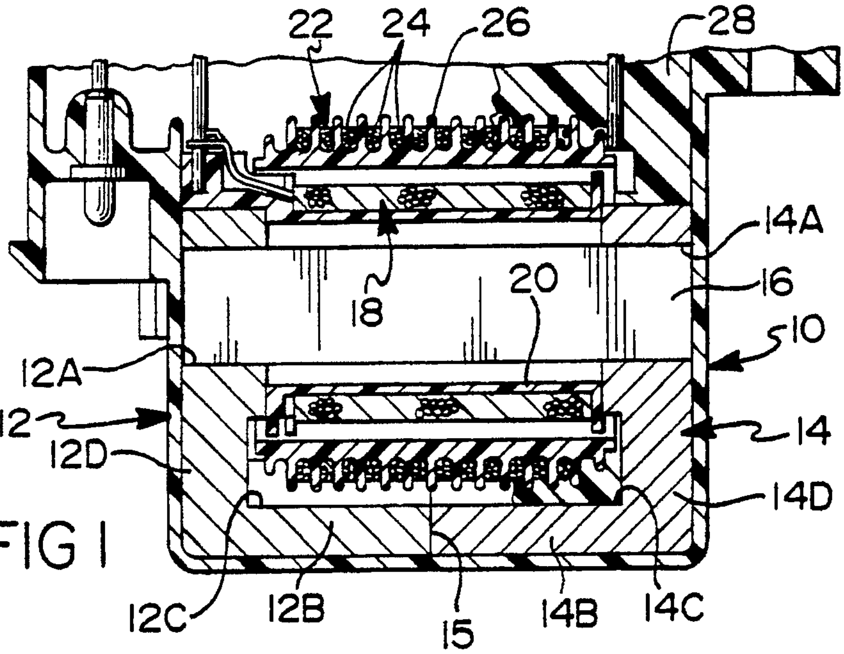

FIG 1

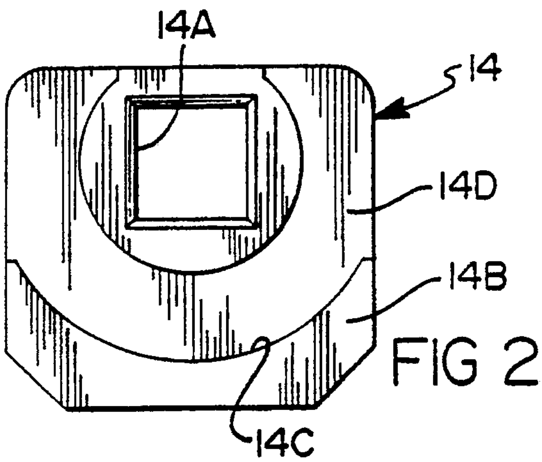

FIG 2

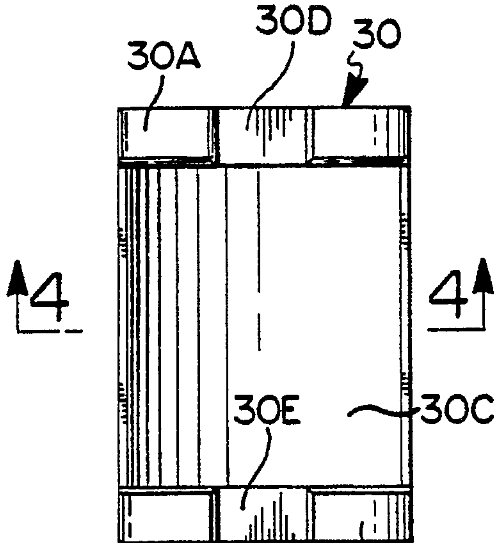

FIG 3

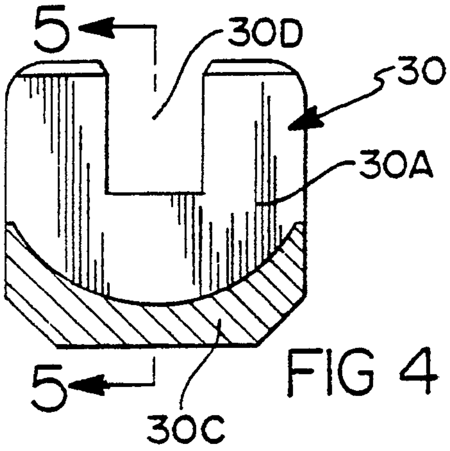

FIG 4

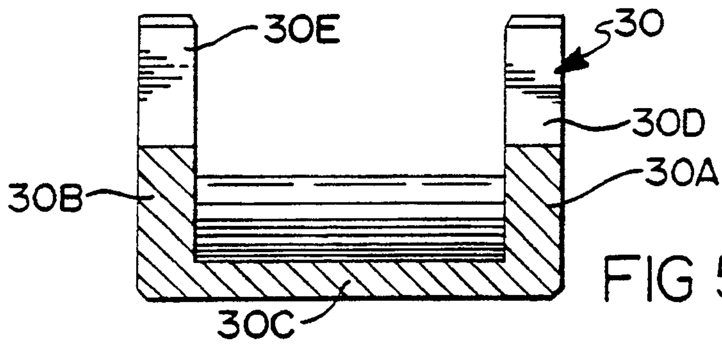

FIG 5

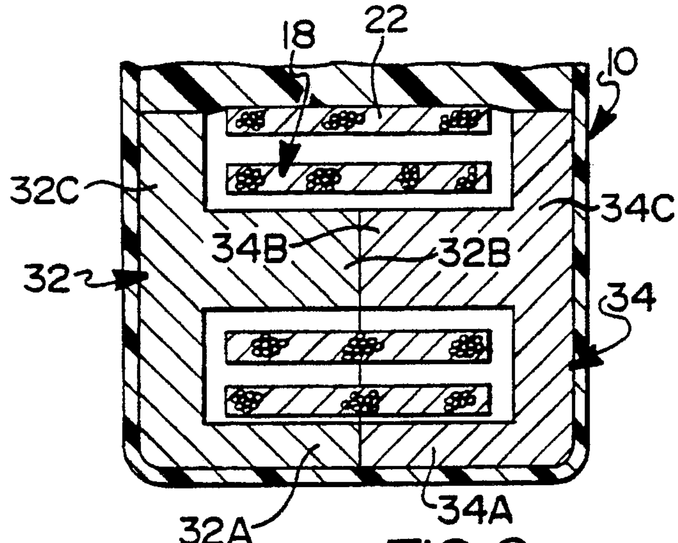

FIG 6

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 90 30 8121

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
Y,A	GB-A-2 211 669 (KIJIMA CO LTD) * page 10, line 17 - page 11, line 2 * - - -	1,4-6	H 01 F 31/00 H 01 F 27/255
Y,A	EP-A-0 241 068 (N.V.PHILIPS' GLOEILAMPEN-FABRIEKEN) * column 2, lines 41 - 47 * - - -	1,2	
Y	EP-A-0 112 577 (TOKYO SHIBAURA DENKI K.K.) * page 19, lines 1 - 9 * - - -	1	
A	US-A-3 668 589 (PIONEER MAGNETICS,INC.,) * column 2, lines 22 - 31 * - - - - -	7	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)
H 01 F

The present search report has been drawn up for all claims

Place of search	Date of completion of search	Examiner
The Hague	08 November 90	VANHULLE R.

CATEGORY OF CITED DOCUMENTS

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