

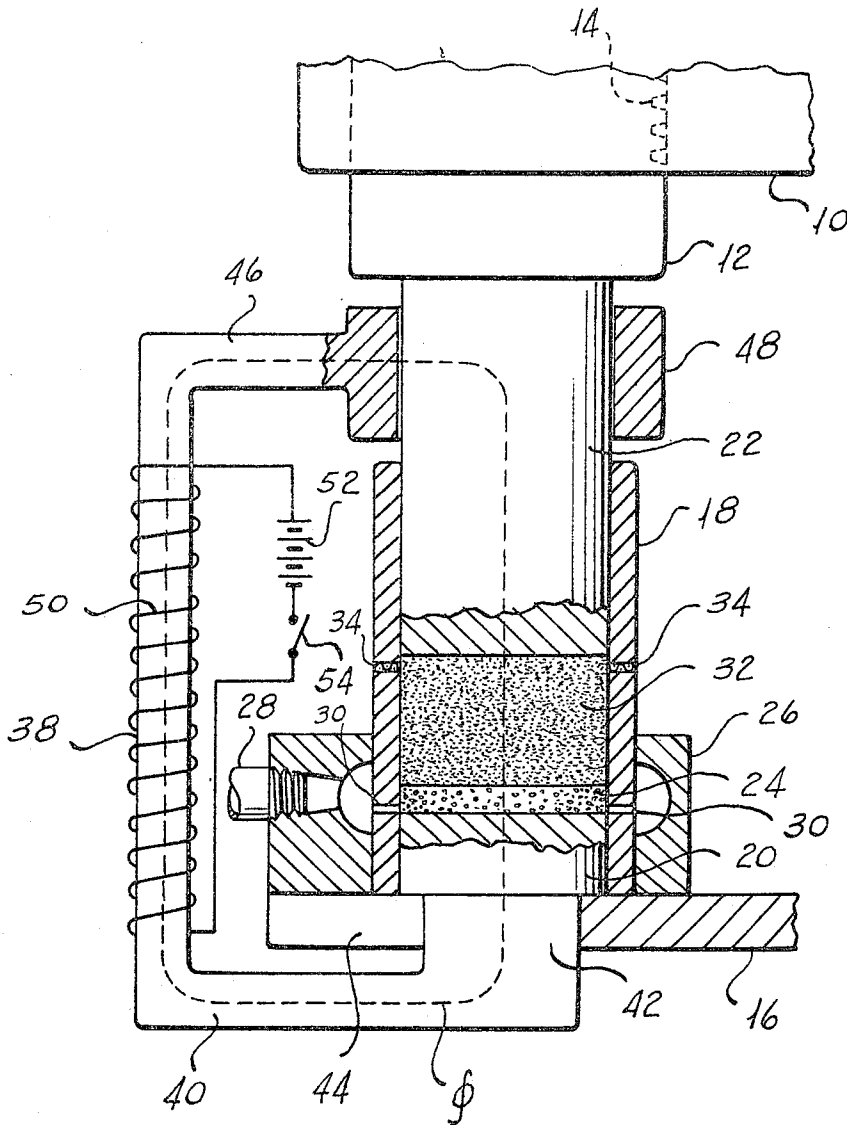
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METHOD OF COMPACTING FERRITE PARTICLES

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METHOD OF COMPACTING FERRITE PARTICLES
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My invention relates to a method of compacting ferrite particles and more particularly to a method for producing ferrite material having improved magnetic properties.

Ferrite is a powdered compressed and sintered magnetic material having a high resistivity. Owing to the high resistivity of materials of this class, eddy current losses are extremely low so that the material is especially useful in high frequency circuits. Materials of this class are spinels, garnets and hexagonal ferrites. Specifically barium ferrite, nickel ferrite, nickel-cobalt ferrite, manganese-magnesium ferrite and yttrium-iron garnet are examples of ferrite material. In the microwave and UHF range ferrites are used extensively in isolators, circulators, duplexers, switches, variable attenuators, phase shifters, harmonic filters, limiters and paramagnetic amplifiers. At relatively lower frequencies (below about 100 mc.) they may be used in filter inductors, antenna cores, fly-back transformers, TV deflection yokes, IF transformers, magnetic memories, computer switches and magnetic amplifiers.

In the manufacture of a ferrite article such, for example, as a magnetic encoder disc or a core, powdered ferrite material first is compressed and then heated to sinter the material. The magnetic property of a ferrite material is determined by the degree of orientation of the particles during the compacting process. Owing to this fact, it has been suggested in the prior art that the powdered material be subjected to a magnetic field as it is being compressed so as to produce a better orientation of the particles with the resultant improved magnetic properties of the finished article. Further to enhance the degree of orientation, it has been suggested that water be added to the powdered ferrite to form a slurry which is compressed in a die at extremely high pressure while the material is under the influence of a magnetic field. Following compression, a sample must be dried and then slowly heated up to sintering temperature.

The methods of the prior art described above embody a number of disadvantages. First, the method which merely employs a magnetic field acting on the powder during compacting does not produce the optimum orientation of the particles. While the method in which a water slurry is formed before compaction produces superior orientation of the particles, it embodies a number of difficulties. First, the equipment required to extract water from the slurry during compaction is cumbersome, difficult to operate and expensive. Moreover, this process requires a step of drying the article after compression and before it is heated to sintering temperature. Owing to this fact, the process is relatively slow. Also, the resulting product is not as dense as is desirable.

I have invented an improved process for compacting ferrite particles which overcomes the defects of processes of the prior art. My process results in a ferrite article in which the degree of orientation of the particles is optimized. My process does not require the extraction of water during the compacting operation. My process does not require any drying step following the compacting operation. The article produced by my process is a high density, substantially void-free and highly oriented ferrite.

One object of my invention is to provide a method of compacting ferrite particles with a high degree of orientation.

Another object of my invention is to provide a method of compacting ferrite particles which does not require the removal of water during the compacting process.

A further object of my invention is to produce a method of compacting ferrite particles which does not require a step of drying the compacted article.

Yet another object of my invention is to provide a method of producing high density, substantially void-free and highly oriented ferrite articles.

Still another object of my invention is to provide a method of compacting ferrite particles which overcome the defects of methods and apparatus of the prior art.

Other and further objects of my invention will appear from the following description.

In general my invention contemplates the provision of a method of compacting ferrite particles in which I first form a gas-fluidized bed of ferrite particles and compress the bed while subjecting the particles to the influence of a magnetic field. Following this initial compression step, the magnetic field can be removed and the intermediate article compressed to the degree required to prepare it for sintering.

In the accompanying drawing which forms part of the instant specification and which is to be read in conjunction therewith, the figure is an elevation with parts in section of one form of my apparatus for practicing my method of compacting ferrite particles.

Referring now to the drawing, one form of my apparatus for practicing my method of compacting ferrite particles includes a press crown 10 which carries a press ram 12 having teeth 14 or the like by means of which the ram can be driven toward the press bed 16. Since the details of presses of this type are well known and since the particular press employed does not per se form part of my invention, the remaining parts of the press will not be described in detail.

My apparatus includes a die 18 which is formed from any suitable nonmagnetic material. The die 18 may have any appropriate cross-sectional shape. For example, where I desire to form a disc of ferrite the die 18 has a generally circular cross section. The die 18 is adapted to receive a plug 20 supported on the table 16 and a plunger 22 for acting on the ferrite particles to be described hereinafter. In a manner known to the art, ram 12 descends to act on the plunger 22 to drive it toward the plug 20 to exert the required pressure on the ferrite particles to be described. I form both plug 20 and plunger 22 of magnetic material to facilitate passage of magnetic flux therethrough.

During the initial compression step of my process, I place a grid 24 formed from a suitable porous ceramic over the plug 20. A manifold 26 surrounding the die 18 adjacent the lower end, as viewed in the figure, is supplied with a gas, such as air, under pressure from a pipe 28. Gas under pressure supplied to the manifold 26 through pipe 28 flows into the gas grid 24 through openings 30 in the wall of the die 18. After having placed the plug 20 and the gas grid 24 within the die 18, I place a charge 32 of the ferrite particles to be compressed into the die 18 over the grid 24. Next the plunger 22 is moved into the die 18 over the bed 32. Gas under pressure supplied to the manifold 26 passes into the grid 24 and flows upwardly through the particles to produce the gas fluidized bed 32. Screened ventilation holes 34 in the wall of the die 18 permit the gas flowing upwardly through the bed 32 to escape through the walls of the die 18.

The form of my apparatus shown in the figure includes a magnet indicated generally by the reference character 36 having a core 38 formed with a bottom leg 40 having a pole 42 disposed in a slot 44 in the table 16 under the plug 20. I form the upper leg 46 of the magnet 36 with

a collar 48 surrounding the plunger 22. A winding 50 carried by the core 38 is adapted to be energized from a battery 52 or the like upon closure of a switch 54 to produce a magnetic flux following the path indicated by the broken lines in the figure. It will be seen that when switch 54 is closed, flux flows from the core 38 through the pole 42, the plug 20, the gas grid 24, the fluidized bed 32, the plunger 22 and collar 48 and leg 46. In this manner the fluidized bed 32 is subjected to the influence of the orienting magnetic field during the compacting process. Owing to the fact that the ferrite particles are suspended in the gas, they are relatively free to move toward the orientation to which they are influenced by the flux passing through the bed.

In the particular form of my apparatus shown in the figure, I have indicated the plug 20 and plunger 22 as being formed of a magnetic material such, for example, as steel. If desired, I could employ porous ceramic ferrite material for the plug 20 and plunger 22 to eliminate the need for the gas grid 24. While this would result in a better path for the flux, owing to the elimination of the air gap resulting from the nonmagnetic ceramic grid 24, uniformity of the field would be sacrificed. The form of my apparatus shown in the figure is the preferred embodiment.

In operation of the form of my apparatus shown in the figure to practice my method of compacting ferrite particles, I first place the plug 20 in the die 18 and dispose the ceramic grid 24 over the plug 20 at a location at which it can receive gas from the manifold 26 through the holes 30. When this has been done I place the charge of ferrite particles over the grid 24 and move the plunger 22 into the die over the particles. I maintain the plunger 22 within the die by any suitable expedient such as by moving the press ram 12 down toward the die 18. Next I introduce a dry gas which may, for example, be air into the manifold 26 through pipe 28 to cause a flow of gas up from the grid 24 through the particle charge and out through the screened vents 34 thus to form the gas fluidized bed 32.

Once the gas fluidized bed has been formed so that the particles of ferrite are relatively free to orient themselves, I close switch 54 to produce a flux passing from the pole 42 through plug 20, the grid 24, the bed 32 and plunger 22 to the leg 46. Under the influence of this field the ferrite particles tend to orient themselves with the field. I now operate the press to move the ram 12 down to exert a pressure of from about 500 to about 5,000 p.s.i. on the particles in the fluidized bed. It will readily be appreciated that the particular pressure value is not critical. It depends largely upon the size of the ferrite particles being compacted.

Following this initial compression step I shut off the gas supply and open switch 54 to remove the magnetic field. I now remove the air grid 24 so that the partially compacted ferrite article is directly in engagement with the plug 20. When this has been done, I again move ram 12 down to apply the required full pressure to the partially compacted article to compact it to the degree required. This final compression is at a pressure of from about 10,000 to 100,000 p.s.i. again depending on the particular compound being acted on. The most desirable pressure to be employed for any particular material can readily be determined by testing the magnetic properties of the resultant article. After this final compression step, the compressed ferrite article is removed from the die 18 and elevated to a temperature which is suitable for sintering the material. While I have shown a separate magnet 36 it will readily be appreciated that the required flux may be produced in a winding wrapped around the die 18.

It will be seen that I have accomplished the objects of my invention. I have provided a method of compacting ferrite particles which overcomes the defects of methods of the prior art. My method produces a high density, substantially void-free and highly oriented ferrite. My method does not require the removal of water during the compacting step. My method does not require that the article be dried after compression and before sintering.

It will be understood that certain features and subcombinations are of utility and may be employed without reference to other features and subcombinations. This is contemplated by and is within the scope of my claims. It is further obvious that various changes may be made in details within the scope of my claims without departing from the spirit of my invention. It is, therefore, to be understood that my invention is not to be limited to the specific details shown and described.

Having thus described my invention, what I claim is:

1. A method of compacting ferrite particles including the steps of forming a gas-fluidized bed of ferrite particles to be compressed, subjecting the particles in said bed to the influence of a magnetic field and compressing said particles while in said gas fluidized bed and while under the influence of said field.

2. A method of compacting ferrite particles including the steps of forming a gas-fluidized bed of ferrite particles to be compressed, subjecting the particles in said bed to the influence of a magnetic field, compressing the particles in said bed to a predetermined degree while in said gas fluidized bed and while under the influence of said field to form an intermediate article and then compressing said intermediate article to a degree greater than said predetermined degree.

3. A method of producing a ferrite article including the steps of forming a gas-fluidized bed of ferrite particles to be compressed, subjecting the particles in said bed to the influence of a magnetic field, compressing the particles in said bed to a predetermined degree while in said gas fluidized bed and while under the influence of said field to form an intermediate article, then compressing said intermediate article to a degree greater than said predetermined degree and sintering said article to form a finished ferrite article.

4. A method of compacting ferrite particles including the steps of depositing a charge of particles to be compressed on a grid of porous material, supplying gas to said grid to form a fluidized bed of said particles above the grid, subjecting said particles to the influence of a magnetic field, compressing the particles in said bed to a predetermined degree while in said gas fluidized bed and while under the influence of said magnetic field to form an intermediate article for removing said grid and compressing said intermediate article to a degree greater than said predetermined degree.

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