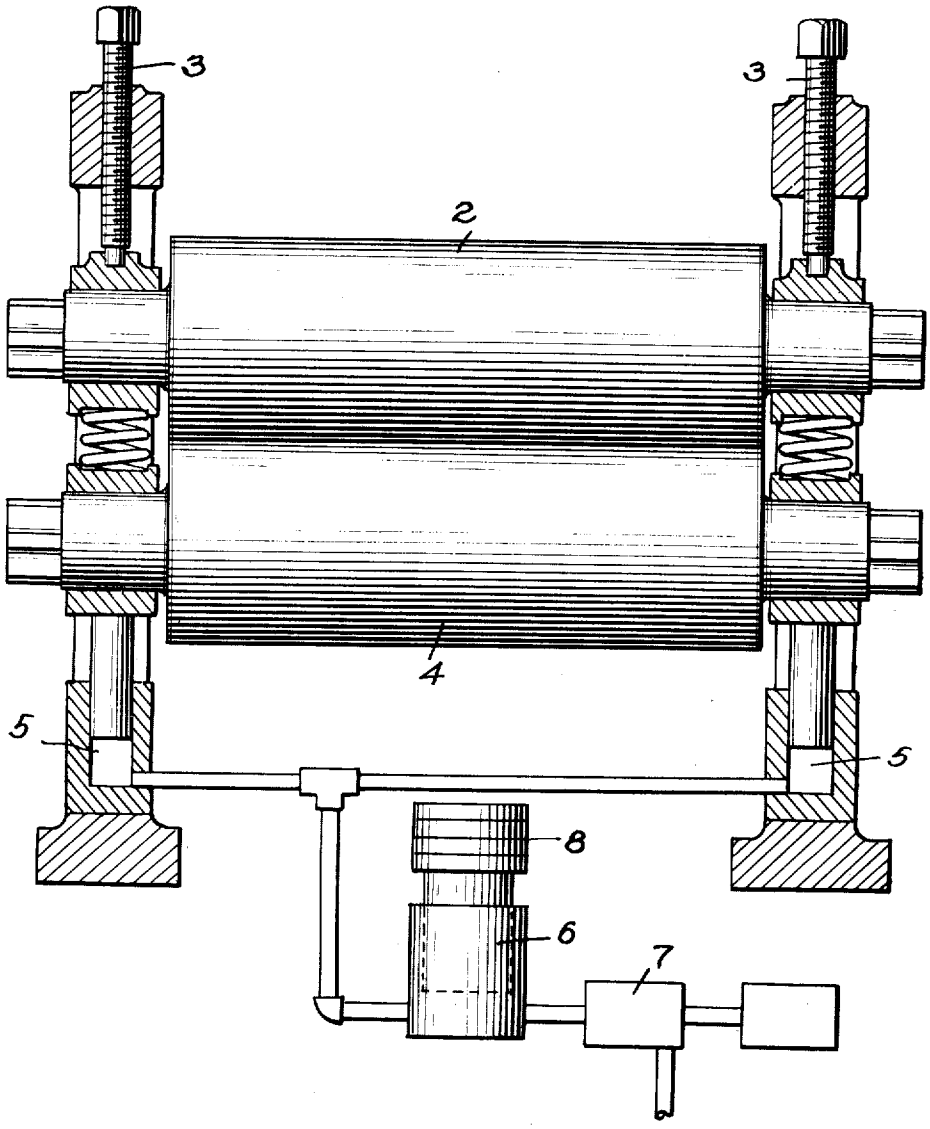
V. B. BROWNE.

METHOD OF CONTROLLING THE GRAIN GROWTH IN MAGNETIC ALLOY SHEETS.

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1,367,015. Patented Feb. 1, 1921.



WITNESSES

J. Herbert Bradley.

INVENTOR

Vm B. Browne

By Jno. Thos.
His Atty.

UNITED STATES PATENT OFFICE.

VERE B. BROWNE, OF TARENTUM, PENNSYLVANIA.

METHOD OF CONTROLLING THE GRAIN GROWTH IN MAGNETIC ALLOY SHEETS.

1,367,015. Specification of Letters Patent. Patented Feb. 1, 1921.

Application filed June 6, 1919. Serial No. 302,165.

To all whom it may concern:

Be it known that I, VERE B. BROWNE, a citizen of the United States, and a resident of Tarentum, in the county of Allegheny and State of Pennsylvania, have made a new and useful Invention in Methods of Controlling the Grain Growth in Magnetic Alloy Sheets, of which the following is a specification.

This invention relates to the manufacture of magnetic alloy sheets.

The magnetic qualities of alloy sheets such as silicon steel sheets, silicon-aluminum-steel sheets, silicon-manganese-steel sheets, etc., used in building up the laminated structures of electrical apparatus having alternating magnetic fields are in a large part due to the grain size of the metal after annealing.

Within certain limits, the larger the grain size the greater is the magnetic permeability and the lower the hysteresis action. The eddy losses, however, increase with an increase in grain size, and, in order to obtain a magnetic material of suitable permeability and hysteresis action with permissible eddy losses it is necessary to effect a compromise between large and small grains.

It has been found that the grain size is due, at least in part, to the strain which the metal of the partially finished sheets is subjected to before annealing. The greater the strain the smaller will be the grain size and conversely the lower the strain the greater will be the grain size. The strain depends upon the temperature of the metal and the pressure to which it is subjected. The higher the temperature for a given pressure the smaller will be the strain and consequently the lower the temperature for a given pressure the greater will be the strain, likewise the higher the pressure for a given temperature the greater will be the strain and the lower the pressure for the same temperature the smaller will be the strain. The greater the strain the lower may be the annealing temperature after the sheets are finished. In order to control the grain size in the finished sheets it is necessary to control the pressure to which the sheets are subjected in the finishing pass or passes in accordance with the rolling temperature, and I therefore preferably utilize a mill in which the roll pressure may be made to be a definite unvarying pressure for each temperature.

I have found that not only the magnetic qualities but the physical qualities as well are materially improved if the alloy is not abruptly subjected to intense temperatures.

I have also found that the desired qualities in the finished sheets are dependent to some extent upon the manner of heating the partially finished sheets between passes and the manner of annealing the sheets after the final pass.

Magnetic alloy sheets made in accordance with any of the prior processes with which I am familiar do not run uniform. The sheets of one pack not only differ in magnetic and electrical characteristics from those of another but portions of the same sheet vary and the prime object of this invention is to provide a method whereby magnetic alloy sheets having the desired qualities may be produced in commercial quantities; a method whereby high quality sheets may be uniformly produced without at the same time producing inferior sheets.

By this process I have found that sheets of magnetic material of uniform quality can be produced and that such sheets will have increased electrical and magnetic values over sheets made by any of the prior processes with which I am familiar.

According to this process magnetic alloy sheets are made in the following manner.

I first melt down and refine in either an open hearth or an electric furnace (preferably an open hearth furnace) a charge of pig iron with iron and steel scrap and any or all of the fluxes and reagents commonly employed. After the impurities encountered are oxidized and eliminated in any desired manner until the carbon reaches .20% or such point as in each individual case represents the stage just before that at which the iron of the bath begins to suffer oxidization, the product is transferred from the furnace to a ladle containing the molten or preheated alloys; silicon and manganese in the form of ferro silicon and ferro manganese, if the magnetic alloy is to consist of a steel alloyed with silicon and manganese, and ferro silicon only if the alloy is to consist of a steel alloyed with silicon and aluminum; the aluminum being added to the ladle during tapping. The molten

metal is preferably allowed to remain tranquil for a definite period before being tapped. In this way I am enabled to obtain ingots of exceptional purity as to the iron content and of the proper analysis as to the alloys.

The next step in my process consists in heating these ingots slowly to approximately 1200° F. before bringing them to a rolling temperature. This step is important for the reason that if a magnetic alloy such as a silicon steel alloy is abruptly subjected to intense temperatures, incipient cracks tend to develop which I have found have a very marked detrimental influence on the ultimate magnetic qualities of the finished sheets.

The ingots after being brought to the rolling temperature are rolled in the usual manner into commercial sheet bars. The sheet bars are also slowly heated to a temperature of 1200° F. in order to prevent the formation of incipient cracks and then raised to the rolling temperature.

Under the common practice now used in forming sheets a "run over pack" is produced from one or more sheet bars by suitable heating, rolling, pairing, matching, doubling or otherwise manifolding and any or all of these steps may be taken in any desired number or combination. The "run over pack" is then usually given a finishing heat in a furnace and then rolled out to length. The result so far is a finished pack which has the same length and thickness as the "run over pack" but on account of the doubling has twice as many ply. The finished pack is then usually sheared, opened and annealed. Under my method the step after raising the sheet bars to rolling temperature is to reduce the bars to sheets in the form of a pack by any standard practice so far as the rolling, pairing, matching and doubling is concerned. The necessary heating between passes however, during this step is of prime importance and is conducted in a muffle furnace so constructed and operated that the sheets are kept out of contact with the heating flame and if desired they may be surrounded by any suitable atmosphere such as a reducing, a neutral or an oxidizing atmosphere depending upon the characteristics desired in the finished sheets. Whatever the atmosphere, however, it is important that no undesirable deposits form on the sheets as such deposits tend to separate the sheets and prevent proper rolling.

I have found that the magnetic qualities of the finished sheets are greatly enhanced if the sheets just prior to the final pass or passes are raised to a temperature not lower than red and preferably orange. I have found that the best results occur when the sheets are heated to a temperature at or above that at which the former structure of the metal disappears or is modified according to the laws of metallography. The pressures to which the sheets are subjected during the rolling operations subsequent to such heating are controlled in accordance with the degree of heat used in obtaining such structure modification, so that the strain produced in the sheet metal is such that the grain in the finished sheets after annealing is of a size predetermined to be the proper size to give to such sheets the desired permeability and hysteresis action with permissible eddy losses.

The roller after such heating preferably takes place as soon as possible and before any perceptible lowering of temperature occurs so that the sheets may be discharged from the mill at about the temperature of recalescence.

For the purpose of controlling the rolling pressures to which the sheets are subjected after that heating at which the former structure of the metal disappears or is modified I prefer to use a mill in which the bottom roll is yieldingly supported so as to give a constant predetermined unvarying pressure irrespective of any irregularities in the pack either as to temperature or thickness and in order to accomplish this the bottom roll is mounted on hydraulic cylinders connected up to an accumulator so loaded as to produce a predetermined unvarying roll pressure; such pressure being determined in accordance with the degree of temperature to which the pack is brought before such pass or passes.

In the drawings accompanying and forming a part of this application I have diagrammatically illustrated such a mill and in this the top roll 2 is adjusted by means of screws 3 in the ordinary manner, the bottom roll 4 is mounted on hydraulic cylinders 5, 5 connected up to an accumulator 6 supplied with water by means of a suitable pump 7 and loaded by means of weights 8 to give the desired roll pressure. By varying weights 8 the roll pressure may be varied and so long as the accumulator operates an unvarying predetermined roll pressure will be maintained.

By means of a mill as above outlined, for a given temperature of pack, a predetermined unvarying strain can be given to the metal which, in the finished sheets, after annealing, will promote a definite grain growth, and, by controlling the roll pressure in accordance with the rolling temperature a uniform product, or sheets which are uniform in magnetic qualities, can be produced.

After final reduction of the sheets to finished form the sheets are allowed to cool, are sheared and opened and then annealed in any approved manner preferably at a

temperature which will fully promote the grain growth due to the strain to which the sheets have been subjected in the final pass or passes; box annealing is preferable. The word "sheets" used herein is to be construed broadly and is not to be limited as to any certain gage or gages.

Having thus described my invention, what I claim is—

1. The method of making silicon steel sheets from an ingot which consists in gradually heating the ingot to approximately 1200° F. then in raising the temperature thereof to forging temperature, then in reducing the ingot to sheet form and during said reduction in carrying on the necessary heating between passes in an oxidizing atmosphere, and also in controlling the pressure exerted upon the sheets in the final pass or passes in accordance with the temperature thereof whereby a predetermined grain size will be provided in the finished sheets after annealing, and then in annealing said sheets to attain grain growth.

2. The method of making silicon steel sheets from an ingot which consists in gradually heating the ingot to approximately 1200° F. then in raising the temperature thereof to forging temperature, then in reducing the ingot to sheet form and controlling the pressure exerted upon the sheets in the final pass or passes in accordance with the temperature thereof whereby a predetermined grain size will be provided in the finished sheets after annealing, and then in annealing said sheets to attain grain growth.

3. The method of controlling the grain size in silicon steel sheets, which consists in gradually heating an ingot to approximately 1200° F. then in raising the temperature thereof to forging temperature, then in reducing the ingot to sheet form and during said reduction in carrying on the necessary heating between passes in a neutral or reducing atmosphere, and also in controlling the pressure exerted upon the sheets in the final pass or passes in accordance with the temperature thereof whereby a predetermined grain size will be provided in the finished sheets after annealing, and then in annealing said sheets to attain grain growth.

4. The method of controlling the grain size in silicon steel sheets, which consists in gradually heating an ingot to approximately 1200° F. then in reducing the ingot to sheet form and controlling the pressure exerted upon the sheets in the final pass or passes in accordance with the temperature thereof whereby a predetermined grain size will be provided in the finished sheets after annealing, and then in annealing said sheets to attain grain growth.

5. The method of making silicon steel sheets from an ingot which consists in gradually heating the ingot to approximately 1200° F. then in raising the temperature thereof to forging temperature, then in reducing the ingot to sheet form and during said reduction in carrying on the necessary heating between passes of contact with the heating flame, and also in controlling the pressure exerted upon the sheets in the final pass or passes in accordance with the temperature thereof whereby a predetermined grain size will be provided in the finished sheets after annealing, and then in annealing said sheets to attain grain growth.

6. The method of making silicon steel sheets from an ingot which consists in gradually heating the ingot to approximately 1200° F. then in raising the temperature thereof to forging temperature, then in reducing the ingot to sheet form and during said reduction in preventing the formation of deposits thereon, and also in controlling the pressure exerted upon the sheets in the final pass or passes in accordance with the temperature thereof whereby a predetermined grain size will be obtained in the finished sheets after annealing, and then in annealing said sheets.

7. The method of making silicon steel sheets from an ingot which consists in gradually heating the ingot to approximately 1200° F. then in raising the temperature thereof to forging temperature, then in reducing the ingot to sheet form and during said reduction in carrying on the necessary heating between passes in such manner that no undesirable deposits are formed thereon, and also in controlling the pressure exerted upon the sheets in the final pass or passes in accordance with the temperature thereof whereby a predetermined grain size will be obtained in the finished sheets after annealing, and then in annealing said sheets to attain such grain size.

8. The method of making silicon steel sheets from an ingot which consists in gradually heating the ingot to approximately 1200° F. then in raising the temperature thereof to forging temperature, then in reducing the ingot to sheet form and during said reduction in carrying on the necessary heating between passes out of contact with the heating flame, and also in controlling the pressure exerted upon the sheets in the final pass or passes in accordance with the temperature thereof whereby a predetermined grain size will be obtained in the finished sheets after annealing, and then in annealing said sheets to attain grain growth.

9. The method of producing magnetic alloy sheets, which consists in starting with an ingot of the desired analysis, in slowly heating said ingot to approximately 1200° F., then in raising it to rolling temperature and rolling sheet bars therefrom, then in slowly heating said sheet bars to approximately 1200° F., then in raising them to

rolling temperature, then in reducing said bars to sheet form and in conducting the necessary heating between passes in a beneficial atmosphere, and in raising the temperature of the partially finished sheets prior to one of the final passes to a temperature at which the former structure of the metal disappears or is modified, and in controlling the pressure exerted upon the sheets subsequent to said heating in accordance with the degree of such heating whereby the metal of such sheets is given a predetermined definite strain.

10. The method of producing magnetic alloy sheets, which consists in starting with an ingot of the desired analysis, in slowly heating said ingot to approximately 1200° F., then in raising it to rolling temperature and rolling sheet bars therefrom, then in slowly heating said sheet bars to approximately 1200° F., then in raising them to rolling temperature, then in reducing said bars to sheet form and in conducting the necessary heating therefor between passes out of direct contact with the heating flame, and in raising the temperature of the partially finished sheets prior to one of the final passes to a temperature at which the former structure of the metal is modified, and in controlling the pressure exerted upon the sheets subsequent to said heating in accordance with the degree of such heating whereby the metal of such sheets is given a predetermined definite strain.

11. The method of controlling the grain size in steel sheets after annealing, which consists in heating the sheets to not lower than the ordinary reheating temperature and giving them a final reducing pass between rolls mounted so that a constant roll pressure is always exerted but not exceeded and in discharging the sheets from said rolls at or about the critical point of the metal.

12. The method of controlling the ultimate grain size in silicon steel sheets, which consists in heating the sheets to not lower than the ordinary reheating temperature and giving them a final reducing pass between rolls mounted so that a constant roll pressure is always exerted but not exceeded and in discharging the sheets from said rolls at or about the critical point of the metal.

13. The method of controlling the grain size in silicon steel sheets, which consists in heating the sheets to a temperature above the ordinary reheating temperature and then giving them a final reducing pass between rolls mounted so that a constant roll pressure is always exerted but not exceeded and in discharging the sheets from said rolls at or about the critical point of the metal.

14. The method of controlling the grain size in steel sheets, which consists in heating the sheets to a temperature above the ordinary reheating temperature and then giving them a final reducing pass between rolls mounted so that a constant roll pressure is always exerted but not exceeded and in discharging the sheets from said rolls at or about the critical point of the metal.

15. The method of controlling the grain size in silicon steel sheets, which consists in heating the sheets to a temperature above the ordinary reheating temperature and then quickly giving them a final reducing pass between rolls mounted so that a constant roll pressure is always exerted but not exceeded and then in annealing the sheets.

16. The method of controlling the grain growth in silicon steel sheets, which consists in raising a pack of such sheets to a temperature at which the metal structure is modified and then in giving them a pass through rolls and in controlling the roll pressure during such pass so that it always reaches but does not exceed a certain determined pressure.

17. The method of controlling the grain growth in steel sheets, which consists in raising a pack of such sheets to a temperature at which the metal structure is modified and then in giving them a pass through rolls and in controlling the roll pressure during such pass so that it always reaches but does not exceed a certain determined pressure.

18. The method of finishing silicon steel sheets, which consists in completing the final mechanical reduction of a pack at an unvarying pressure irrespective of irregularities in the pack.

19. The method of finishing silicon steel sheets, which consists in completing the final mechanical reduction of a pack at an unvarying pressure irrespective of irregularities as to temperature.

20. The method of finishing silicon steel sheets, which consists in completing the final mechanical reduction of a pack at an unvarying pressure irrespective of irregularities as to thickness.

21. The method of finishing silicon steel sheets, which consists in completing the final mechanical reduction of a pack at an unvarying pressure irrespective of irregularities as to temperature and thickness.

22. The process of making silicon sheet steel from the ingot, which consists in reducing the ingot to sheet form in any ordinary manner until the sheets of a pack have attained nearly but not quite the required thinness, then reheating the pack to a temperature not lower than the ordinary reheating temperature and then reducing the sheets to the desired thinness by one or more passes between suitable rolls so mounted that the roll pressure during such pass or passes always reaches but does not exceed a certain determined pressure.

23. The process of controlling the grain

size in silicon steel sheets, which consists in heating silicon sheet steel to a temperature not lower than the ordinary reheating temperature and giving to it in the reheated condition a final reducing pass between rolls one of which is yieldingly supported whereby a determined pressure is approximated but not exceeded.

24. The method of making silicon steel sheets from an ingot which consists in gradually raising the temperature of the ingot to approximately 1200° F. and thereafter to rolling temperature, then in forming sheet bars therefrom, then gradually raising the temperature of such bars to approximately 1200° F. then in reducing such bars to sheet form and during said operation in carrying on the necessary heating in a muffle furnace and then reducing the sheets to the desired thinness by one or more passes in which the roll pressure is controlled so that it always approximates but does not exceed a certain determined pressure.

25. The method of making silicon steel sheets from an ingot which consists in gradually raising the temperature of the ingot to approximately 1200° F. and thereafter to rolling temperature, then in forming sheet bars therefrom, then gradually raising the temperature of such bars to approximately 1200° F. then in reducing such bars to sheet form and then reducing the sheets to the desired thinness by one or more passes in which the roll pressure is controlled so that it always approximates but does not exceed a certain determined pressure.

26. The process which consists in completing the final mechanical reduction of silicon sheet steel at about the temperature of recalescence and in exerting but not exceeding a predetermined pressure during such reduction.

27. The method of promoting the desired grain growth in silicon steel sheets which consists in completing the final mechanical reduction of silicon sheet steel at about the temperature of recalescence and at an unvarying predetermined pressure and then annealing at a temperature dependent upon the strain produced in the metal during such reduction.

In testimony whereof, I have hereunto subscribed my name this 2nd day of June, 1919.

VERE B. BROWNE.

Corrections in Letters Patent No. 1,367,015.

It is hereby certified that in Letters Patent No. 1,367,015, granted February 1, 1921, upon the application of Vere B. Browne, of Tarentum, Pennsylvania, for an improvement in "Methods of Controlling the Grai Growth in Magnet Alloy Sheets," errors appear in the printed specification requiring correction as follows: Page 2, line 80, for the word "roller" read *rolling;* page 3, line 70, after the word "passes" insert the word *out;* and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 22d day of March, A. D., 1921.

[SEAL.]

M. H. COULSTON,

Commissioner of Patents

Cl. 148—12.