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PROCESS OF MANUFACTURING SHAPED BODIES FROM IRON POWDERS

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This invention relates to the production of shaped sintered iron bodies of the character of steel or alloy steel, from powdery initial material.

Heretofore it was difficult or impossible to produce by sintering steel-like articles shaped ready for use, of desirable density, carbon content, as well as mechanical properties from powdery initial material.

Powdery sponge iron could be compacted under pressures amounting to from 10 to 20 tons per sq. inch into briquets and sintered, however, this sort of iron is impure, relatively expensive and not always available, and the sintered bodies are very soft and porous or deformed.

Electrolytic iron of highest purity can be compacted into shaped bodies at pressures amounting to about 50 to 60 tons per sq. inch and sintered; it is however very expensive and the sintered bodies are extremely soft, porous or deformed. Powders of commercial cast iron containing about 2% to 4.5% carbon, cannot be commercially and satisfactorily compacted at all, even if pressures up to 100 tons were applied previous to sintering; slip faces are apt to develop during pressing which render the material useless for most purposes. By the admixture of pure iron powder to the cast iron powder, a porous body results upon sintering which does not exhibit the character of steel.

Ordinary kinds of steel powders when pressed up to even 200 tons per sq. inch result in fragile compacts, developing slip faces and being practically useless for further manipulation and treatment.

It has been suggested therefore to produce iron powder of predetermined carbon content (steel powder) by desoxidizing and thereafter carburizing finely divided iron oxide, and subsequently decarburizing those not yet briquettable particles in superficial layers so as to obtain individual grains consisting of a core comprising iron and combined carbon and a case or shell of substantially pure iron. The pure iron cases or shells render the particles briquettable under pressure; upon sintering, however, more or less dense compacts are obtained which are neither rigid nor tough. This process also is relatively expensive and requires great care in its performance.

It has also been suggested to carburize iron to predetermined amount, to quench the steel so obtained and to break it up into particles of desired size. These particles are incapable of being molded to desired shaped compacts, and were annealed so as to render them relatively soft and briquettable. This process also is difficult as to the control of the uniform carbon content of the particles, and the latter cannot be compacted easily. By annealing a pearlite, or pearlite-cementite, or pearlite-ferrite structure is imparted to the particles depending upon their carbon content, and their ability of being welded together in a sintering process without simultaneous application of high pressure is poor.

It has also been suggested to carburize iron powder, to dilute it with pure iron powder and thereby to enhance the compressibility of the mix, press the mixture to shape, sinter the shape within austenitic temperature range and to continue that heating until the carbide comprised by the carburized iron is uniformly diffused through the mass. Instead of carburized iron, steel powder could be used. This method obviously requires a long extended heating at relatively high temperatures and is therefore rather uneconomical.

It is therefore an object of the invention to produce shaped sintered bodies of the character of steel, in a less expensive and more efficient way than heretofore.

It is another object of the invention to use in a compacting and sintering process normally (i. e., under commercially practicable pressures) non-briquettable powders of steel, as available in the market without substantially affecting and particularly changing the carbon content of those powders before compacting them.

It is a particular object of the invention to produce dense and shaped sintered bodies from different kinds of iron powders, one of which is substantially ferritic, while the other or others contain up to 1.7% combined carbon and at least one of which is normally not briquettable.

It is still a further object of the invention to produce by sintering shaped bodies from two or more kinds of iron powder, one of which is substantially pure iron or ferritic in character, while at least one other kind forms a carbon to below 1.7% containing iron alloy which is normally not briquettable, the heterogeneous and dense body so obtained having a desired average carbon content and offering desirable mechanical and/or thermal and heat treating qualities, such as to tensile strength and deformation and/or malleability.

It is a further object of the invention to produce by commercially practicable pressures and sintering, shaped bodies from two or more kinds of iron powder, one of which is substantially pure iron or ferritic in character, while at least one

ther forms steel or an alloy thereof, which is ormally not briquettable, and to consolidate hem into a heterogeneous body of desired aver- ge carbon content, desired density and mechani- al and/or thermal properties.

It is possible to manufacture substantially pure nd soft iron powder or ferrite by desoxidizing at levated temperatures finely divided iron oxide in ne presence of a desoxidizing medium, such as nely divided lampblack or hydrogen, carbon onoxide gas, gaseous hydrocarbons, and in par- cular methane or natural gas.

It is obvious that ferritic iron powder obtained this or any other way, such as from pure elec- olytic iron, or particularly from reduced sponge on, is plastic, malleable and ductile, and that its rticles are capable of being welded together en in the cold under suitable and commercially racticable pressure.

Ferritic iron powder is used according to the vention in amounts from about 5% to 70% but referably only up to 40% to 60%, as a binder for her iron powders containing combined carbon d/or other admixtures, if desired, as used in loyed steels and which are, at least in part, nor- ally not briquettable. Tungsten, molybdenum, romium, cobalt, nickel, tantalum, vanadium, licon, titanium, manganese and phosphorus ay be mentioned by way of example as such mixtures.

In particular, the ferritic iron powder is used a binder in admixtures to other powders of eel or alloyed steel, in order to render briquetta- e the mixture containing those normally non- riquettable powders.

Steel powder is available in the market as ushed steel, either in particle sizes suited for e purpose of the invention, or sieved in order separate from coarser particles the finer ones apted for the invention. If no powder of steel desired description is available or if for other asons manufacture of the steel powder is pre- rred, this can be done in well known manner heating scrap sheets, shot or ingots of steel to out 700° to 900° C. and above (but below melt- g temperature), quenching and thereafter ushing the brittle steel to desired particle size; ushing and sieving may be repeatedly applied til desired small particle sizes are obtained. ose powders are normally not briquettable.

The invention is however not limited to the e of steel powder. Powders of alloy steel such containing molybdenum, tungsten, tantalum, nadium, silicon, phosphorus, manganese, nickel, romium and/or cobalt, furthermore of stainless el, nicrom, etc., may be used, in order to intro- ce desired admixtures into the final body. If r reasons to be described hereinafter, ratios of ose admixtures are desired which are not pres- t in steel or iron alloys available in the market, e alloys may be prepared in a well known man- r, the molten alloy solidified by quenching and ereafter crushed and preferably sieved.

In preparing an initial mixture of the binder d up to 1.7% combined carbon and, if desired, her admixtures containing iron powder, in gen- al the following different ways can be taken. r simplicity's sake, only ferritic iron powder d steel powder are referred to in the following scription, but it should be understood that in- ad of steel powder, powders of alloy steel alloy in general, powders of iron containing up to % combined carbon and any other desired ad- xture, and powdery mixtures, can be used. It ould also be understood that instead of one kind of steel powder, different kinds of steel powders, particularly steel and alloy steel powders, or in general, two or more different kinds of iron pow- ders containing up to 1.7% combined carbon and other desired admixtures may be used at least one of which is normally not briquettable.

First, fine ferritic iron and equally fine steel powder may be admixed; this can be done for any kind of powders and purposes. Second, relative- ly coarse ferritic iron powder and fine steel pow- der may be admixed; this is of certain advantage for low carbon steel powders (containing up to about .8 C). Third, fine ferritic iron powder and coarse steel powder may be admixed; thereby the ferritic powder can be easily smeared around the steel particles during mixing in ball mills in the cold or heat which is particularly advantageous if relatively large amounts (up to about 50%) of binder are used. Fourth, coarse ferritic iron pow- der and equally coarse steel powder may be ad- mixed.

While for the purpose of this description of the invention powders of a particle size corresponding up to about 100 mesh may be conveniently called coarse powders, those of particle sizes correspond- ing to a higher mesh number, such as up to 200 to 325 mesh, may be called fine powders. It should be understood, however, that this distinc- tion is not a rigid or critical one.

In choosing the powders, first the price is to be considered. The finer the particle size, the more expensive is the powder. The finer the powders, the lower pressures and shorter periods of sinter- ing may be applied. Second, the ratio of the fer- ritic binder and steel powder in the mixture play an important part in the selection. The larger the amount of binder, the coarser the particles can be. Third, although a heterogeneous product is eventually obtained, the average carbon content of the sintered body depends upon the ratio in which ferritic and particularly pure iron powders are admixed with other kinds of iron powder, containing combined carbon. The average amount of other additions, such as mentioned above, present in the completed sintered body also depends upon that ratio. In the latter re- spect it is to be observed that during the sin- tering process and particularly depending upon its duration, a more or less complete diffusion of carbon from the combined carbon containing powder particles into the ferritic particles occurs, as shall be described more in detail later on, and in the same way other admixtures, such as men- tioned above, diffuse more or less from the iron or steel alloy particles into the ferritic ones.

Thus the ultimate properties, structure and composition of the sintered and cooled body greatly depend upon the initial mixture and the ratios and particle sizes of the different kinds of powders admixed.

In general, according to the invention, the ferritic iron or binder may be used in amounts from about 5% to 70%, balance substantially iron powder or powders containing up to 1.7% com- bined carbon and/or other admixtures of the type referred to above.

The different kinds of iron powder thus chosen are to be intimately mixed, and whatever the size of the powder particles may be, mixing in ball mills, particularly using steel balls and steel linings, has proved advantageous. Mixing may be performed at room or elevated temperatures.

Mixing in ball mills may either be carried out in dry or wet mills. In the latter case, carbon tetrachloride, acetone, benzine, etc. may be used

as proper wetting agents. Also water in which up to about 1% lamp black or graphite is suspended, may be used. In this case the temperature should be room temperature and in any event below the evaporation temperature of the wetting agent. Whenever wet milling is applied, the intimate mixture eventually obtained is to be dried and precautions must be taken against oxidation.

The mixture prepared as described above in general is ready for pressing under commercially practicable pressures, e. g., 10 to 50 tons p. s. i. into a coherent compact of desired shape. However, it is sometimes desirable to interpose a particular preparation of the powders. To this effect any of the 4 types of mixtures referred to above, but preferably consisting of fine ferrite and coarser steel powders of about .3 to .8 C content, is filled into a boat of steel or other suitable material and pushed through a furnace of the continuous operation type, in which a temperature preferably up to 500° to 600° C. and an inert or reducing atmosphere is maintained. The latter may be produced by the use of desiccated hydrogen, carbon monoxide, natural gas, nitrogen, cracked gases, etc. The heat treatment may be applied for a considerable period of time, from about 20 minutes to one hour or longer. In place of a stationary furnace, a rotary furnace may be used in which additional mixing or even ball milling of the powders is combined with the intended heat treatment.

The preliminary heat treatment just described results in some boundary diffusion between the particles of ferrite and those of the other powder or powders, or a sherardisation of the latter. It should be observed, however, that by this heat treatment, if applied, the structure and particularly the composition of the individual particles should not be changed materially and only, in general, the combined carbon containing steel particles be provided with a mechanically adhering film of more ferritic character.

The thus preliminarily treated mixture may be pressed immediately or further comminuted in a dry ball mill.

The above preliminary treatment is particularly advantageous if relatively small amounts of ferritic binder are used, such as from 5% to 15%. In such cases, but also in the presence of higher amounts of ferritic binder it has been found that the pressures to be applied for compacting can be considerably reduced, or the period of presintering or sintering at highest temperature somewhat shortened.

The mixture prepared in any way described above is now subjected to compacting into coherent bodies of desired shape in molds.

A particular object of the invention consists in manufacturing shaped products of steel or alloy steel character containing between .1% to 1.5% combined carbon, by sintering from an initial mixture of suitable powders. Ferritic iron powder is substantially spongy and relatively plastic. Steel powder obtained from eutectoid steel contains about 0.9% carbon and is either of pearlitic or martensitic structure. Steel powder obtained from hypereutectic steel is either martensitic or pearlitic and cementitic in a structure, while powder obtained from hypoeutectoid steel is either martensitic or pearlitic and ferritic. The powder particles obtained from any such brittle steel are sharp, angular and extremely hard and therefore apt to interlock with and to pierce into the soft, spongy and malleable ferritic particles under pressure, whereby the coherence of the pressed body is assisted.

Due to the presence of binder of ferritic, soft and malleable iron, the compacting can be performed under commercially practicable pressures ranging from about 3 to 50 but preferably to 25 and 30 tons per sq. inch. The higher the amount of binder present, the lower may be the pressure. With an amount of binding material of 20% to 25%, pressures of between 20 and 30 tons per sq. inch generally suffice. With an amount of 30% to 50% of ferritic binder a pressure of about 10 to 25 tons per sq. inch suffices. If powders are pretreated to obtain sherardizing effects in the way described above, pressures from 3 to 15 tons per sq. inch suffice, the lower values pertaining to 50% to 60% binder and the higher values to about 20% to 30% ferritic binder present. In order to facilitate the shaping and compacting at very low pressures, it is sometimes desirable to admix a binder, such as dextrine, glucose, or a polyvalent alcohol, such as glycerine, in small amounts of about 1% to 2% by weight of the entire mixture. Such binder evaporates or burns off at low temperatures during presintering or when final sintering is started, and such evaporation does not result in porosity of the final body. If an organic binder is used and carbonized, it adds to the carbon content of the mixture which is to be taken into consideration when the final carbon content of the body is calculated. The pressure also depends on the particle size and loading weight of the powder, and the finer and lighter particularly the powders of binding material are, the lower may be the pressure. In the pressed and coherent body thus obtained the particles of all the powders used in the initial intimate mixture are uniformly distributed. Though the body is still porous, the particles are brought into intimate contact and the shapes of the soft ferritic powder particles are closely adapted to those of and interlocked with the harder combined iron containing particles. Thereby effective sintering within periods as short as possible is considerably assisted. The coherence of the pressed bodies suffices for taking them out of the molds and subjecting them to sintering. Due to the presence of the soft ferritic binder which also acts like a lubricant, the wear of the dies during pressing and by ejecting the pressed bodies is minimized.

The shaped pressed bodies are either immediately subjected to high and final sintering, or first to presintering. It is well known in the art that presintering temperature is about 20% to 30% below the melting point of the mixture, and if presintering is desired, the pressed bodies are subjected to such temperatures (between about 750° to 1050° C.) for a controlled period of time, and preferably for about 10 to 60 minutes. Precautions against undesired oxidation or decarburization are to be taken by performing presintering in an inert or reducing atmosphere, such as desiccated hydrogen, etc.

If carbon containing gases are used, such as natural gas, hydrocarbons, generator gas, etc., they are to be diluted by other gases, such as hydrogen, if slight additional carburization of the body under treatment is to be avoided.

A presintering step is desirable in some cases for well known reasons, particularly in order to remove oxide films from particles and to degasify the body and to shorten the final sintering period. The presintered body may be pressed again in

the cold or heat, and/or shaped additionally, e. g., by machining.

The pressed, and if desired, presintered bodies are then subjected to final sintering. The temperatures of final sintering depend considerably upon the character of the mixture. It is well known in the art that the melting point of iron depends upon the amount of combined carbon, and other admixtures alloyed therewith. While pure iron melts at about 1550° C., its melting temperature decreases to about 1150° C. with increasing carbon content up to 4.2%; with further increased carbon content the melting temperature slowly increases again, but iron with such high carbon content is of no practical interest for the present invention which is confined to the manufacture of shaped iron bodies containing about .1% to 1.5% C. Within the lower part of this range, up to about .95% C, the invention is particularly suited for the manufacture of more complicated shapes, such as those having undercuts, or whenever great accurateness is required, such as for gears and tools, while ordinary steel with a carbon content of about .3% to .5% (rarely .6%) carbon can still be used with advantage for more simple shapes and those not requiring machining for accurateness after casting. In the range above 1.5% carbon, malleable cast iron which contains above 2% carbon can be used, and the invention does not pretend to compete with such malleable cast iron.

It is well known that final or high sintering temperatures lie in general about 10% below the melting point of a metal or mixture of metals capable of sintering, and thus it is easily possible to calculate or establish by analysis the average carbon content of the entire mixture of iron powders, then to establish from well known iron-carbon diagrams the melting temperature of iron with that carbon content, and to calculate therefrom the final sintering temperature to be expected; the latter can easily be verified by a few experiments.

The same holds true for mixtures containing, besides ferritic iron and steel, also other admixtures such as mentioned above. The ranges of melting temperatures of those iron or steel alloys are well known, and by calculating from the ratios of the individual melting temperatures of different kinds of powders, the approximate average melting temperature of the mixture, and from the latter the final sintering temperature to be expected, a basis is found for eventually establishing the actual final sintering temperature of the mixture by a few experiments.

Thus in general the final sintering of powder mixtures according to the invention will be accomplished within a temperature range from about 1150° C. to about 1390° C. It should be observed, however, that the highest sintering temperature of any powder is by no means as fixed a value as the melting temperature, but actually covers a range above and below the theoretical value; it should, however, always be considerably below a temperature at which the entire mixture or any part of it melts.

The period of sintering depends to some degree upon the size of the powdery particles; the finer the particles the shorter that period. It also depends upon the size of the article to be made since the heat penetrates faster through a small article than through a larger one. With this understanding, the average period of sintering should be given with about 10 minutes to one hour.

It is to be understood that the carbon content of the steel powder will define the average carbon content of the sintered product. Assuming a mixture consisting of 25% of powdery ferritic binder and 75% powdery steel of 0.8% carbon content, the average carbon content of the final body will amount to .6% carbon, provided no carbon is burned off by an oxygen containing atmosphere and sintering is consequently performed either in an atmosphere inert or neutral to carbon, or in vacuo.

If a higher average carbon content of the final mixture is desired, particles of steel of higher carbon content, up to about 1.5% should be used.

It is evident that in such a case also two or more kinds of steel powders may be admixed; one of the lower carbon content, e. g., .8% carbon, the other of the higher carbon content, e. g., 1.5% carbon, and the ratios of the ferritic iron, as well as of the two kinds of steel powders are to be calculated so as to result in the desired average content of carbon.

Any suitable furnace can be used for sintering, such as push furnaces of the continuous operation type as described above for desoxidizing purposes, and in particular resistance or induction (high frequency) furnaces. Any protective, in particular inert or reducing or even carburizing atmosphere may be used during sintering, or a vacuum applied. Sintering may also be performed under pressure, if desired in more exceptional cases.

As to the operation of the high sintering process, the following should be understood although the inventor does not intend to confine himself to any theory of his invention.

During high sintering at temperatures of or exceeding 1150° C., not only compacting and agglomerating of the powdery particles occurs, as is the case in ordinary sintering processes like in the production of hard metals which contain carbide particles bonded by iron group metal, or in other composite bodies of the structure of agglomerates.

While in ordinary sintering processes aiming at mere agglomeration, a binder of lower melting point than the other components of the mixture is used and becomes highly plastic or even melts while the other components remain substantially solid, it should be observed that the ferritic binder used by the invention is mostly of the highest melting point of all components of the mixture. However, according to the invention the ferrite is used as a convenient binder for compacting the mixture preferably in the cold under commercially practicable pressures, and during final sintering the binder and the combined carbon containing components obviously exchange their roles; those components become highly plastic first, cause shrinking of the mass and closest contact between them and the ferritic particles as well as most probably wetting of the latter, thereby diffusion of carbon into the intimately contacting ferritic particles and lowering of their sintering temperature is accomplished gradually, resulting eventually in a substantially equal sintering temperature of all particles present in the mixture and their complete sinter.

However, if the desired final sintering temperature is considerably lower than about 1300° C. and if a relatively large amount of ferritic binder is present, it is sometimes advisable to heat the

mixture at the start of sintering at least to about 1300° C. and to gradually reduce that starting to the desired final sintering temperature after about 5 to 20 minutes have passed and some diffusion of carbon into the ferrite has occurred. At 1300° C., steel even of 1.7% carbon content will be still solid though highly plastic.

In general, and if the articles are not too large, during the period while the mixture is heated up to sintering temperature sufficient diffusion of carbon into the ferritic particles will occur, whereby their sintering temperature is lowered and that the steel particles is raised (because their content of combined carbon is correspondingly reduced), and sintering can be performed throughout at the desired final temperature without using the temperature regulation described above.

Thus, by properly choosing the ratio of carbon present in the mixture to the entire iron amount of the latter, and controlling the temperature and period of sintering, the mass gradually adopts the character of austenite, if the total amount of carbon compared to the total amount of iron present in the mass does not exceed about 1.5%. At high temperatures exceeding about 1360° C., the maximum limit of carbon allowing formation of austenite gradually decreases.

Upon slowly cooling the mass from sintering temperature to room temperature, upon passing the temperature corresponding to the transformation point A_3, the mass if austenitic in character and containing about .9% carbon, converts itself into pearlite while a higher carbon content results in pearlite plus cementite and a lower carbon content into pearlite plus ferrite. If due, e. g., to controlled final sintering at lower temperature or for a shorter period than necessary to cause carbon to diffuse into all of the ferritic binder, a part of the latter remained virgin, the cooled product consists of a phase of that virgin ferrite, and other phases resulting from the remaining mass which at sintering temperature either was austenitic or austenite plus cementite. The structures of these other phases depend on the carbon content of that remaining mass; if the latter contained .9% carbon, pearlite results, while with a higher carbon content pearlite plus cementite and with a lower carbon content pearlite plus additional ferrite (which may be conveniently called secondary ferrite) results.

If a mass of any of the types referred to is subjected to controlled particular quenching, martensite results.

From this it follows that from a process according to the invention, upon controlled sintering and cooling in general, a material of the shaped body greatly resembling or equalling ordinary steel results.

If for one reason or the other, controlled sintering to this effect cannot be performed in a single step, and a true steel is desired, the shaped body can be pressed again preferably in the heat and at temperatures close to but below its melting temperature in molds of a shape and size taking into account any shrinkage during the first sintering. Pressing by exerting a heavy stroke is preferred. The thus pressed body is then sintered for a second time, and these operations repeated, if necessary, until the desired structure or density is obtained.

From the above it also appears that by controlled sintering and cooling according to the invention the final structure of a mass of given composition can be definitely determined. While by sufficiently extended sintering in general pearlite, or pearlite-cementite, or pearlite-ferrite, or martensite, result, by reducing the period or temperature of sintering the diffusion of carbon into the ferritic binder can be checked to a desired extent and upon cooling a mass will result which, besides pearlite, etc., also contains a kind of virgin ferrite matrix, resulting from those portions of ferrite into which, due to the shortened sintering period or the lower temperature applied, no carbon has diffused.

If the initial mass contained a steel alloy, the process applied according to the invention for manufacturing the desired shaped bodies is substantially the same as described. The phenomenae occurring during controlled sintering depend however on the capability of the admixture to diffuse from the steel alloy into the ferrite particles. While cobalt, nickel and molybdenum diffuse quite easily, manganese and chromium diffuse slowly and to a limited extent, particularly if they are present in relatively large ratios in the added alloy. Thus, the final shaped body will be of alloy steel character, and the admixtures will either be uniformly distributed throughout, or be present only or mainly in particles or crystals resulting from the originally admixed alloy steel particles. However, the finer the original powders are, and the more thorough the sinter, the more the distribution of difficultly diffusing admixtures will resemble a uniform distribution, and the body will exhibit properties almost completely resembling those of alloyed steel.

It is evident from the foregoing that the ratio of admixtures of the type referred to in the final body will depend upon its total amount introduced by the steel or iron alloy in proportion to the total mass of iron present. Due to the presence in the initial mixture of ferrite in substantial amount, a substantial dilution of those admixtures results. If the final body therefore is to contain a certain ratio of such an admixture, a steel alloy of correspondingly higher content of such admixture should be chosen, which, upon dilution by the added ferrite results in the desired ratio. If steel of such composition is not available on the market, particular alloys or prealloys of iron and the desired admixture should be prepared and added to the initial mixture in suitable amount. Such alloys are also available in the market, and ferromanganese, ferromolybdenum, ferronickel, ferrosilicon, ferrotitanium, ferrovanadium, stainless steel (scrap), ferrochrome and ferrotungsten can be used for this purpose. The admixture may be added, however, also in powdered virgin state and not alloyed with iron, etc. to the initial mixtures.

The shaped body obtained according to the invention can be subjected to any further treatment. If it is finished in a desired shape, ready for use, it might be case hardened or hardened by annealing and quenching, or normalized, or softened and somewhat more homogenized by annealing only. If the body is, e. g., in the shape of a rod or ingot, it might be subjected to mechanical treatment such as slicing, forging, drawing, extruding, pressing, rolling, etc. It can also be machined. If its constitution or structure should not allow such mechanical treatment, the latter may be adapted to the treatment by annealing or any other heat treatment.

The structure of the final body and the grain size depend in part upon that of the initial ma-

terial, particularly if virgin ferrite is retained, and can also be affected by proper control of temperature or period of sintering, as well as by the manner of cooling the body. Thus grain size, or crystal growth and recrystallisation can be well controlled. Care should be taken that the carbon content is maintained and that decarburization be avoided by the use of proper protecting atmospheres at temperatures where decarburization might otherwise occur.

If for any reason, such as for the purpose of saving on relatively expensive desiccated hydrogen, some decarburization should occur during sintering, it can be taken care of by admixing to the initial mixture steel particles of higher carbon content or in larger relative amount which, upon being partly decarburized still yield the desired average carbon content of the final iron mass. To the same effect, solid carbon such as lamp black may be admixed to the initial powder before pressing.

If for any other reason carburization occurs during sintering, for instance because natural gas (methane) is available at low cost, this should be taken care of by dosing the carbon containing components of the mixture, so that upon carburization during sintering, the desired average content of carbon of the iron mass results.

For some molding purposes a certain minimum loading weight of the initial powder is desired. The loading weight of powdery sponge iron is mostly about 1.5 gr./cc., and that of steel powder 3 to 3.5 gr./cc. By proper dosing the ferrite and steel components according to the invention, desired loading weights of the initial mixture can be obtained. Thus 40% to 60% of ferritic iron powder (150 mesh) of 1.5 loading weight, have been admixed with a balance of steel powder (150 mesh) containing 0.7% C and having a loading weight of 3.5; the resulting mixtures had a loading weight of 2.4 to 2.6 which is demanded for many large scale briquetting (and sintering) purposes.

In the appended claims the term "normally not briquettable" or similar terms are to describe the quality of a powder not to form coherent bodies of desired shapes capable of being further manipulated, upon cold molding under "normal" pressures, i. e., up to about 50 tons p. s. i.

It should be understood that the invention is not limited to any exemplification herein described, but is to be derived in its broadest aspect from the appended claims.

What I claim is:

1. In a method of producing from powdery material by compacting under pressure and sintering shaped bodies substantially of the character of steel or alloy steel and essentially free of graphite, the steps of intimately admixing powder selected from the group consisting of steel and alloy steel powders, at least a substantial part of said powder always containing combined carbon in an amount from .1% to below 1.7% and being normally not briquettable, with about 5% to about 70% ferritic iron powder, shaping and compacting the mixture under pressure, and heat treating the shaped compact under controlled conditions until a predetermined amount of said carbon diffused into said ferritic iron and a dense body of predetermined composition of steel or alloy steel is obtained, said conditions including final sintering at controlled temperatures close to but below the prevailing lowest melting temperature of any of said powders and final body within the temperature range of 1150° to about 1390° C. and application of a selected atmosphere.

2. In a method of producing from powdery material by compacting under pressure and sintering shaped bodies substantially of the character of steel or alloy steel and essentially free of graphite, the steps of intimately admixing at elevated temperatures up to about 600° C. powder selected from the group consisting of steel and alloy steel powders, at least a substantial part of said powder always containing combined carbon in an amount from .1% to below 1.7% and being normally not briquettable, with about 5% to about 70% ferritic iron powder, shaping and compacting the mixture under pressure, and heat treating the shaped compact under controlled conditions until a predetermined amount of said carbon diffused into said ferritic iron, and a dense body substantially of the composition of steel or alloy steel and of predetermined average content of combined carbon within the range of .1% to 1.5% carbon is obtained, said conditions including final sintering close to but below the prevailing lowest melting temperature of any of said powders and final about 1390° C. and application of a selected atbody within the temperature range of 1150° to about 1390° C. and application of a selected atmosphere.

3. In a method of producing from powdery material by compacting under pressure and sintering shaped bodies substantially of the character of steel or alloy steel and essentially free of graphite, the steps of intimately admixing powder selected from the group consisting of steel and alloy steel powders, at least a substantial part of said powder always containing combined carbon in an amount from .1% to below 1.7% and being normally not briquettable, with about 5% to about 70% ferritic iron powder, shaping and compacting the mixture under pressure, presintering said shaped compact at temperatures from about 750° to below 1050° C. in a selected atmosphere, and heat treating the shaped compact under controlled conditions until a dense body substantially of the composition of steel or alloy steel and of predetermined average content of said combined carbon within a range from .1% to 1.5% carbon is obtained and a predetermined amount of said carbon diffused into said ferritic iron, said conditions including final sintering close to but below the prevailing lowest melting temperature of any of said powders and final body within the temperature range of 1150° to about 1390° C. and application of a selected atmosphere.

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