Patented Sept. 3, 1940

2,213,523

# UNITED STATES PATENT OFFICE

2,213,523

## MANUFACTURE OF METAL ARTICLES OR MASSES

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No Drawing. Application February 11, 1938, Serial No. 190,138. In Great Britain October 18, 1937

4 Claims. (Cl. 75—22)

This invention relates to the manufacture of metal articles or masses.

An object of this invention is to provide sintered metal articles or masses from initial materials which have not previously been employed for sintering.

A further object of this invention is to provide metal articles by sintering which either cannot be made by casting or which it is not practicable or economic to make by casting.

A still further object of this invention is to provide a process for producing the aforesaid sintered metal articles or masses.

According to the invention a process is provided for the manufacture of metal articles or masses wherein a powder which is an alloy of iron and carbon with or without small proportions of other constituents which alloy is normally brittle in the cold cast condition is sintered or partially sintered by heating to a temperature below that of general or complete fusion of the alloy, preferably with the application of pressure before, during or after the heating, to cause agglomeration of the particles of powder with formation of the article or mass, the heating being effected in the presence of the small proportion of impurity which is commonly present in the alloy and/or with a small proportion of impurity mixed therewith and which has a bonding action on the particles during the heating.

The process by which it is possible to cause the particles of an alloy of iron and carbon which is normally brittle in the cold cast condition, for example a white cast iron powder prepared by grinding, blowing, or preferably by granulating to agglomerate together under the influence of pressure and heat with the production of articles of high tensile strength and hardness appears to be connected with the action of the various impurities in the alloy particularly with the phosphorus content when phosphorus constitutes an important impurity. It appears that at temperatures higher than 950° C. a fusible constituent consisting of an alloy of iron rich in phosphorus and carbon is formed in iron mixtures which contain sufficient of these elements to permit of its formation.

This fusible constituent appears to be important in that it acts as a cement or binder for the particles of the alloy and when present, it generally leads to the production of superior physical properties. It is obvious that as a starting material it is possible to use:

(*i*) An alloy of iron and any desired quantity of carbon that contains the correct percentage of impurities (for example phosphorus) for the successful formation of a fusible constituent.

(*ii*) An alloy that is deficient in such impurities such as steel turnings, or cast iron drillings or borings, which are low in phosphorus content. In this case it is always possible to make good this deficiency by adding to the alloy small amounts of impurities. For example, in the case of cast iron borings which are low in phosphorus content it is possible to add to such borings small amounts of red phosphorus, or small amounts of an alloy rich in phosphorus such as ferro-phosphorus, phosphor-copper, phosphor-nickel or phosphor-tin. It is also possible to make good the deficiency of such materials in impurities by adding to them other impurities than those which are normally found in them.

(*iii*) An alloy that is too rich in certain impurities. It is possible for example to have an alloy of iron that contains so much carbon or sulphur that the physical properties of the finished article would be seriously prejudiced, or to have an alloy containing so much phosphorus that an undue amount of bonding or cementing agent was formed at the temperature employed and which might cause difficulties in connection with wear of the mould or with extraction of the article from the mould. In such cases as these it is always possible to dilute such impurities and to reduce their influence by adding to the iron alloy to be sintered an alloy of iron which is particularly low in such impurities such as a pure iron powder or a decarburized cast iron grit or shot.

It will be understood that if the powder is subjected to pressure before the heating it may also be subjected to pressure during and/or after the heating and likewise if the powder is subjected to pressure during the heating it may also be subjected to pressure after heating.

The heating may be effected in any desired manner for example heating by gas or electricity. When the heating is effected electrically the powder may be used as a heating resistance.

The process may be carried out with the aid of dies, moulds, or presses and in general a temperature between about 700° and 1200° C. will be employed. Suitable pressures are between about 2 and 60 tons/sq. in.

It is preferred to use as the initial material a cast iron powder finer than 60 mesh (I. M. M. sieve) and from the point of view of cheapness it is advantageous to use a cast iron powder which is at present a by-product, for example a cast iron grit or shot finer than 60 mesh and all

kinds of cast iron borings, millings and drillings which can easily be crushed to powders finer than 60 mesh. Fines produced as waste in the manufacture of ferro-silicon, ferro-vanadium, ferro-titanium and the like may be added to the cast iron if desired. Cast irons or pig irons prepared in the blast furnace in the usual manner or prepared by low temperature reduction processes in the form of sponge or powder containing more than 0.5% of phosphorus and cast irons containing more than 0.5% of silicon are particularly advantageous as initial materials for the process of the present invention.

Moreover it is known that the mechanical properties of the iron-carbon alloys are influenced to a considerable extent by the content and distribution of iron oxide. It is also a fact that it is difficult or impossible to control with any degree of accuracy both the amount and distribution of this oxide by ordinary techniques of casting mainly owing to the considerable difference in specific gravity between iron and its oxide and the mechanical difficulties involved in distributing by stirring a mass of fine iron oxide powder into a melt of molten iron alloy at high temperatures. The process of the present invention however has the additional advantage that it renders possible the control of the oxidation of the iron with any limits desired if necessary from no oxide content to complete oxidation by oxidising the power before or during the heating treatment. This may be achieved by pre-oxidation of the alloy powder before hot pressing by any desired means such as weathering, control of the pressure in cold pressing, control of the period of heating time prior to hot pressing, control of the oxygen content or oxidising properties of the atmosphere in which the powder is heated prior to hot pressing, or by admixture with the powder of oxidising agents such as manganese dioxide. The fragility of masses made in this way can be controlled within very fine limits, and the mode in which fracture takes place under stress is also capable of control. This is of particular advantage in the case of vessels, containers or receptacles intended to contain explosives and designed to be disrupted by the explosive charge contained within them. Examples of the above are as follows: shots for shot firing purposes intended to be loaded with solid carbon dioxide and employed for disrupting masses of stone, or bombs for use in warfare.

The following examples illustrate how the process of the invention may be carried into effect:

1. A white cast iron powder the particles of which have an average diameter of less than 1/60 of an inch is introduced into a circular die which is maintained at a temperature of 1000° C. The powder is then pressed at 10 tons/sq. in. by means of a quick acting press and a compact is produced having a tensile strength of 31 tons/sq. in. and a Brinell number of 254. This compact after suitable machining is used as an orifice disc.

2. A cast iron gear wheel was produced by pressing the powder referred to in Example 1 in a die which is the female counterpart of the gear wheel at a pressure of 5 tons per sq. in. at 1050° C. The pressing had a Brinell number of 269 and was found to have a pearlitic structure when examined under the microscope. The article was heated at 800° C. for 20 minutes in a gas fired muffle furnace and then quenched in sperm oil. After this treatment the Brinell number was 415 and on examination under the microscope the article was found to have a sorbitic structure.

According to the physical properties desired in the finished article the powder particles during treatment may be surrounded by an oxidising, neutral or reducing atmosphere. Normally, it is preferred to employ air as the atmosphere but in certain cases according to the processes customary in the manufacture of articles from metal powders, it is preferred to blow a stream of hydrogen or other reducing gas into the mould or die or to mix with the alloy powder a solid substance such as charcoal which on being heated will produce a reducing atmosphere.

The process of the present invention enables articles to be produced in such shapes and/or sizes which hitherto could only be produced in brittle or hard alloys of iron and carbon by the processes of casting, die casting or by the machining of castings. Examples of such materials which are brittle and impossible or difficult or uneconomic to manufacture to specific shapes other than by the processes of casting or machining are high carbon steels of the type usually known as tool steels, and cast irons more particularly those having their carbon content chiefly in the form of iron carbide ($Fe_3C$), cast irons containing more than .5% of phosphorus and cast irons containing more than 0.5% of silicon.

By the process of the present invention it is possible to manufacture with brittle iron-carbon alloys such articles as gear wheels or blanks, spur-wheels, crankshafts, cam shafts, pistons, cylinder liners, pinions, racks, and the like which previously have had to be made by casting or the machining of castings and where forging, such as is employed in the shaping of less brittle alloys of lower carbon content is an impossible operation.

Further examples of articles or masses which can be made by the process of the invention are all components with thin sections, or abrupt changes in section, which, produced by ordinary casting methods, are apt to possess non-uniform microstructures and physical properties. Blocks, bars, billets and sections for subsequent machining purposes, and it should be noted that these materials can be manufactured in a condition having remarkable free cutting properties. Washers, rings, thrust rings and spacers which are usually characterised by thin sections but required to possess high strength. Containers or vessels required to possess the property of being permeable to gases or liquids, or to be easily ruptured by the discharge of explosives contained within them, but possessing at the same time mechanical properties which render them workable by ordinary machining processes, and capable of being handled in the ordinary manner without fear of breakage. Components requiring extremely dense structures impermeable to gases or liquids and of high strength and resistance to abrasion or corrosion such as cocks, spigots, plugs, cover-plates, valves, unions in chemical plant, hydraulic or oil equipment. The production of a material possessing special structures unobtainable by normal casting or forging technique, such as a controlled zoned structure, or a structure characterised by the distribution of one or more of the micro-constituents in a predetermined manner. The production of structures characterised by the presence of microstructures of a pre-determined size, shape or distribution. The production of articles characterised by the predetermined occurrence of localised areas or volumes possessing special physical, chemical or

mechanical properties, but forming at the same time integral parts of the whole, e. g. areas of a 10% silicon heat and corrosion resisting iron may be produced in a matrix of a low silicon iron. The production of articles characterised by the fact that they are formed around and have embedded in them some pre-formed component, e. g. metallic or non-metallic tubes, insulated heating elements, or inclusions of a higher or lower density than the main body of the article in order to obtain specialised mechanical or balance characteristics, e. g. tungsten spheres may be embedded in the nose of bullets or other projectiles made by the processes described. The production of articles for simultaneous or subsequent forging, pressing, stamping, extrusion, or impact extrusion. The utilisation for high duty structural components of high phosphorus and/or high sulphur iron alloys normally considered as too brittle for such uses without preliminary metallurgical treatment to remove excess phosphorus and/or sulphur. Some particular instances of the above are:

In connection with steam, gas, hydraulic, or internal combustion engines, cylinders, heads, bushings, stuffing box glands, neck rings, piston rings, connecting rods, valves, valve seats, shoes, rods, bearings, and bearing caps, governor parts and rocker arms.

In connection with tubular goods and hydraulic and oil equipment, couplings, flanges, pipe unions, spools, casings, shoes, guides, baffle-plates, orifice discs, pipe T's, standard and high pressure bull plugs and caps, flowbeams, cocks, oil jets, flow plugs, nozzles and injectors.

Miscellaneous—prepressings to be reshaped and repressed, welding rods, pulleys, sprockets, nuts, bolts, screws, shackles, keys, pins, hooks, hinges, handles, clips, knobs, fasteners, chains, brackets, contacts, plates, moulds for pressing operations, bearing housings, for encasing and connecting objects, cone seatings and rivets and cones for clutches.

Improved physical properties can also be obtained in the finished pressing by means of a suitable heat-treatment. In the case of powders obtained from grey cast irons, in some cases the presence of free graphite may interfere with the sintering operation. The graphite may be removed by a suitable washing, cleaning or chemical decarbonising treatment.

An additional advantage of the present invention is that the products produced lend themselves to a certain extent in a manner quite different from similar products manufactured by casting processes to the following shaping operations at elevated temperatures: stamping, forging, hammering, pressing, drawing, rolling and extruding. The explanation of this property probably is that the shaping operation may take place before the individual particles of the alloy are completely agglomerated and that the presence of brittle envelopes surrounding the individual grains of the alloy such as are frequently inherent in a casting process with certain alloys are, owing to the absence of general fusion in the process of the present invention, entirely avoided. Thus it is possible by a choice of operating conditions and initial materials to shape such articles if desired by processes of mechanical deformation at elevated temperatures during or after the initial agglomeration or manufacture. Other advantages of the process of the present invention as compared with the casting process are controlled grain size and shape to an hitherto unachieved extent, controlled distribution of the alloying constituents, the possibility of adding constituents which do not or only partially alloy, elimination of wastage of metal inherent in casting, melting and slagging processes, the use of permanent or semi-permanent moulds, accuracy of sizing, and avoidance of wastage of material in the form of risers and headers.

It will be appreciated that the present invention is not limited to the use of the iron-carbon alloys, hereinbefore specifically referred to but includes the use of all those alloys containing iron and carbon as their chief alloying constituents and which are normally brittle in the cold cast condition.

Examples of other constituents which may be present are nickel, chromium, titanium, molybdenum, vanadium, silicon, phosphorus, sulphur, aluminium oxide, silica, titanium dioxide and other metals or refractory oxides. Refractory oxides such as magnesium oxide or aluminium oxide are valuable additions when it is desired to control the fragility of the iron-carbon alloy.

The masses and articles produced according to the present invention preferably have physical properties within the following ranges:

Tensile strength 4 to 35 tons per sq. in., per cent elongation 0 to 1, Brinell No. 120 to 300 in the annealed condition and 200 to 550 in the heat treated condition, Izod impact value 0 to 5 ft. lbs.

By the expression "alloy which is normally brittle in the cold cast condition" as used herein is meant one which, when fractured under applied stress does so with less than a 1% increase in its linear dimensions.

The term "sintering" as used herein includes fritting that is an operation in which partial fusion of the alloy or the impurities takes place.

The term "article" as used in the appended claims includes mass.

What we claim is:

1. As a new article of manufacture, a sintered agglomerated powder of white cast iron bonded by an iron-carbon-phosphorus eutectic.

2. A process for the manufacture of a metal article, comprising heating a powder of white cast iron containing more than 0.5% of phosphorus as an impurity to a temperature below that of general or complete fusion of the alloy but sufficient to produce at least partial sintering of the powder.

3. As a new article of manufacture, a sintered agglomerated powder of an alloy of iron and carbon bonded by an iron-phosphorus eutectic.

4. As a new article of manufacture, a sintered agglomerated powder of white cast iron bonded by an iron-phosphorus eutectic.

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