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UNITED STATES PATENT OFFICE.

ROBERT ABBOTT HADFIELD, OF SHEFFIELD, ENGLAND.

STEEL.

SPECIFICATION forming part of Letters Patent No. 735,365, dated August 4, 1903.

Application filed March 9, 1898. Serial No. 674,497. (No specimens.)

To all whom it may concern:

Be it known that I, ROBERT ABBOTT HADFIELD, a subject of the Queen of Great Britain, residing at Sheffield, county of York, England, have invented an Improvement in Processes of Making Chromium-Nickel Steel, of which the following description is a specification.

This invention relates to the manufacture at a comparatively low cost of hard steel possessing superior qualities and which can be cast, rolled, and forged like other hard steel, having special susceptibility to hardening with less liability to water-cracking than usual—as, for instance, frequently occurs with ordinary steel—the steel to be hereinafter described being particularly suitable for use in the production of articles of comparatively large sectional area that require to be hardened in the mass—that is to say, practically throughout their section.

One exceedingly useful employment of my novel steel is in the production of projectiles possessing great strength and penetrative powers and specially suitable for armor-piercing and like purposes.

In carrying out my invention I add to a suitable basis of iron, say, about 0.75 per cent. to one per cent. of carbon, two per cent. of chromium, and two per cent. of nickel, care being taken to keep the amount of manganese that may be present at least under 0.3 per cent. and preferably as much lower as possible, as I have found in my experiments that the presence of manganese much in excess of the quantity mentioned causes water-cracking when the steel is hardened. The percentages of carbon, chromium, and nickel may be varied to some extent from those hereinbefore mentioned, provided the resulting product is nearly free from or low in manganese and capable of being readily hardened. Thus the carbon might vary from 0.60 per cent. up to 1.75 per cent., the chromium from about 0.25 per cent. up to five per cent., and the nickel from about 0.25 per cent. up to seven per cent. I have, however, obtained the best results for articles of comparatively large mass with the proportions first mentioned, manganese being practically absent in the resultant product. A solidifying agent may be added to the steel, preferably in a molten condition, for the purpose of obtaining soundness and freedom from blow-holes. Silicon or aluminium, either or both, may be used as the solidifying agent, and when used the silicon may vary in quantity up to about 2.50 per cent., though preferably for most purposes smaller quantities—say of about 0.30 per cent. are sufficient—while the aluminium may vary up to about 0.20 per cent., but preferably for most purposes not more than 0.10 per cent. will be necessary.

A suitable basis of iron for making my improved steel is decarbonized iron, produced by any suitable steel-making process and as free as possible from manganese. The carbon, chromium, nickel, and the solidifying agent may be added in various forms. For example, the carbonizing physic may be in the form of a suitable carbonaceous material—as, for instance, white iron of good pure quality, low in sulfur and phosphorus, and practically free from manganese. The chromium or nickel may be added in the metallic form or in the form of ferrochromium and ferronickel, respectively. Aluminium may be added in the matallic state or in the form of ferroaluminium and the silicon in the form of ferrosilicon. I prefer to add the carbonaceous material and chromium and nickel either as metals or alloys in a melted state to the molten iron in order to facilitate thorough admixture therewith, and so, too, the solidifying agent should be added in a melted state.

In carrying out my invention I take iron—such, for instance, as is now used in the production of acid-steel—and decarbonize it, preferably by the pneumatic method, in a suitable vessel or converter, though it may be by treatment in the ordinary way in an open-hearth furnace, care being taken in either case to eliminate practically the whole of the carbon, manganese, and silicon it may contain. To the molten iron thus obtained I add the carbonizing physic, chromium, and nickel, as hereinbefore described, and preferably also the solidifying agent—that is, aluminium and silicon, either or both. The manner of making these additions is of the greatest importance in producing steel of special high quality, and I proceed as follows, viz: The carbonizing physic is melted in crucibles or in a furnace which is not subject to oxidizing influence, and the molten physic is run into a ladle. For example, a furnace may be used with a basic lining, such as dolomite, or magnesite, or magnesia, or mixtures of these in which the constituent elements of the alloy are not oxidized. Upon the physic the decarbonized iron, as described, is then poured. The addition of the physic in the furnace itself is objectionable because oxidizing influences are at once at work, and consequently steel of such uniformity as I produce cannot be obtained. It is extremely important in order to obtain a satisfactory result that the various additions be made with accuracy, and for this reason they (the additions) should not be made to the molten iron while the latter is in the converting vessel or furnace, as by such procedure it is difficult to insure that the resulting steel shall contain the desired exact proportions of the added substances and shall be of uniform quality. To obviate this difficulty, I prefer to run successively into a ladle or vessel carried by a suitable weighing-machine, such as a Denison weighing-machine or a platform weighing-machine, the desired amounts of carbonizing physic, chromium, nickel, and the solidifying agent, each in a suitable form or condition, such as hereinbefore described, and in a molten state. The desired weights of the several substances, preferably previously melted in crucibles, are thus ascertained in a ready and very exact manner. Into the weighed molten contents of the ladle while the latter is carried by the weighing-machine is then run, preferably direct from the furnace, so much of the molten iron as will increase the weight of the contents of the ladle to that of the required quantity of my special steel, which is then either run off into ingots, which can be afterward forged into articles of desired shape, or it is poured into suitable molds to produce castings.

I have found the commonly-accepted idea that manganese is necessary in steel is to a large extent erroneous, and, in fact, its presence is in many ways very deleterious. In making special high-quality steel—that is, hard steels containing, say, 0.70 to one per cent. of carbon—I find that the lower the manganese is kept the better the product; but when the material is not required to possess hardness primarily—*i. e.*, natural hardness or capacity for subsequent hardening—the advantage to be gained is not so great, as I believe that only in the presence of carbon is the manganese harmful. In other words, manganese may not be objectionable in mild steels—say under about 0.35 per cent. carbon—because in such cases, and they probably represent the majority of uses for which steel is required, the action of the carbon is so much weakened that more or less manganese is immaterial. Manganese is in itself a very hard and brittle metal, and while this in itself may not be an objection, yet I consider that in its action as a carbid of manganese when carbon is present it is most harmful where the special qualities of hardness and toughness are requisite, believing that these qualities cannot be developed if manganese is present in quantity, say, over 0.25 per cent. It is to be borne in mind, however, that I am not referring to large percentages, such as in Hadfield manganese-steel alloys containing over two per cent. up to twenty per cent. manganese, of which I am the inventor and which come under an entirely different category.

Hitherto, so far as I am aware, it has not been known that sound ingots, sound both as regards freedom from unsoundness—that is, honeycombed—and sound as regards forging—that is, free from cracks or other forging defects—could be obtained without the presence of manganese, particularly if silicon or aluminium, or both, be used; but, as hereinbefore set forth, I have discovered this fact, and that with sufficient silicon or aluminium, or both, no manganese is required, while the resultant product can be rolled and forged like other hard steels and hardened and tempered readily, with the cracking not only no more but actually less than with the most expensive crucible steels. I find that with practically no manganese the steel, while hardening equally as well as heretofore, is much tougher and shows a better-looking fracture, all of which goes to show that the absence of manganese has prevented the formation of the very objectionable brittle carbid of manganese.

In the production of high-power projectiles from my improved steel the latter is either cast or forged into suitable shape, and in the former case the steel is run off from the ladle into molds, preferably iron or partly iron and partly sand and provided with suitable cores when the projectiles are to be formed with a bursting-chamber. Solid projectiles may be cast either point or base upward; but in casting chambered projectiles I prefer to cast the lower or ogival part of the projectile in an iron mold, it being possible to thereby cast thinner-walled shells than could be so successfully accomplished if cast entirely in sand or entirely in iron molds. After removal from the mold the projectile is preferably annealed by heating to a suitable annealing temperature—say about 1,600° Fahrenheit in a furnace—and then permitting it to cool slowly. The sinking or feeding head is cut from the casting in any suitable manner, and any necessary machining of the projectile can be performed. The projectile is then hardened, preferably at its point and shoulder portions, and for this purpose these portions are heated to a suitable temperature—say from about 1,500° to 1,700° Fahrenheit—and then quickly dipped point downward into a cooling medium—such as oil or water, or both—at the ordinary temperature, and simultaneously a cooling medium such as indicated is circulated in contact with the interior portion of the projectile. If the projectile is to be forged, an ingot of the steel is forged approximately to shape and then annealed, machined, bored out, if necessary, and hardened, the annealing and hardening being effected in the manner described relative to cast projectiles.

As before stated, the presence of manganese in hard steel tends to render the steel brittle when it is hardened in a similar manner to but to a less degree than phosphorus, and for this reason I regard manganese as a deleterious element in hard steel as sulfur and phosphorus are regarded deleterious in iron and steel, and manganese therefore is an element the presence of which should be avoided as much as possible.

Having fully described my invention, what I claim, and desire to secure by Letters Patent, is—

1. The process of making steel free from or low in manganese, which consists in decarbonizing and demanganizing iron, and adding thereto a carbonizing agent, chromium and nickel, and a solidifying agent.

2. The process of making chromium-nickel steel, which consists in bringing together and mixing molten decarbonized, demanganized and desiliconized iron, a carbonizing agent in a molten state, and molten chromium, nickel, and a solidifying agent.

3. The process of making chromium-nickel steel, which consists in bringing together and mixing molten decarbonized, demanganized and desiliconized iron, a carbonizing agent in a molten state, and molten chromium and nickel.

4. The process of making chromium-nickel steel, which consists in bringing together and mixing in a molten state decarbonized, demanganized and desiliconized iron, a carbonizing agent, chromium, nickel and a solidifying agent, in a ladle or other vessel, and weighing each element in its molten condition, whereby the weight and proportion of each can be readily and accurately controlled.

5. In the process of manufacturing chromium-nickel steel, successively introducing in a molten state a carbonizing agent, chromium, nickel, a solidifying agent, and decarbonized, demanganized and desiliconized iron into a suitable vessel, the several ingredients being weighed in their molten condition, as they are successively introduced to the vessel, whereby the exact weight and proportion of each ingredient may be accurately determined.

In testimony whereof I have signed my name to this specification in the presence of two subscribing witnesses.

ROBERT ABBOTT HADFIELD.

Witnesses:
GEORGE H. HEMSOLL,
HOWARD MARTIN.