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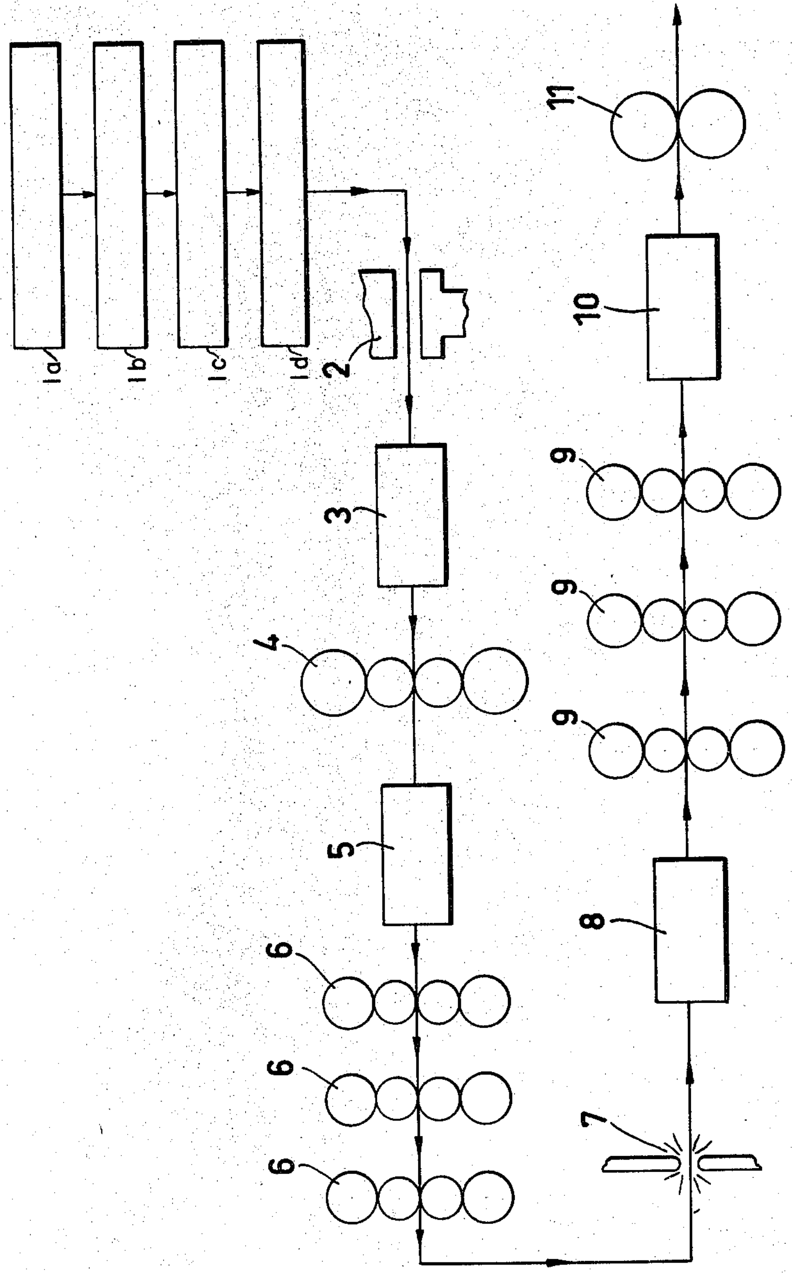

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# METHOD FOR PRODUCING ROLLED STEEL PRODUCTS

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This invention relates to a method for producing rolled steel products, preferably thin sheet, with low oxide content from oxidic iron powder, preferably sponge iron relatively rich in oxide, by imparting to the oxidic iron powder either during its manufacture or thereafter a content of carbon.

The most types of sponge iron show an excellent property of compressibility, rendering it possible to compress porous sponge iron in a rolling mill or press such, that a product of high density and strength is obtained. Even sponge iron in ground state can be compressed in the same manner. By sintering, after-pressing or rolling the compressed products, the strength can be increased still more. This method is applied in so-called powder-metallurgical manufacturing processes.

Neither sponge iron, however, nor sponge iron powder which are produced according to conventional reduction processes is adapted for use in the production of high-grade pressed or rolled products without having been subjected to a special after-treatment. This is partially due to the fact that sponge iron almost always includes considerable amounts of residue iron oxides which may sometimes even exceed 5%. It is easy to understand, that such impurity reduces the strength of compressed sponge iron products and, in general, deteriorates the quality of the material.

In the production of iron powder for powder metallurgical purposes, the content of oxidic impurities usually is reduced by subjecting the sponge iron after grinding to a further reduction by hydrogen gas. Such a reduction process involves, however, considerable costs, depending partially on the hydrogen gas price, nor is it, on the other hand, very effective, because the diffusion paths are relatively long and high temperatures cannot be applied.

It is the object of the invention to eliminate the aforesaid disadvantages or to reduce them to a minimum in those special cases when iron powder is employed for producing rolled products, particularly thin sheet. The invention is substantially characterized in that the carbonaceous and oxidic iron powder is first pressed to sheet bars, that the sheet bars are sintered at 600–1200° C., so that their carbon and oxide contents are substantially reduced, whereafter the bars by compression rolling are formed to billets which, finally, are subjected to cold rolling in conventional manner.

If the production conditions of the iron powder are such, for example according to the Höganäs-method, that its carbon content can be adjusted, it is not necessary to admix further carbon to the iron powder. If, however, the available iron powder is produced according to a method, for example by reduction with hydrogen gas, which does not include the possibility of adjusting the carbon content, a certain amount of ashless carbonaceous material or pig iron powder, cementite or another metallic carbide should be admixed, so that the carbon content of the oxidic iron powder is adjusted to the oxide content of the latter.

Thereafter, the iron powder is compressed.

According to the invention, the pressing of the powder to sheet bars is carried out either with or without binding agents.

In this description, the term "sheet bars" refers to somewhat porous metallic semifinished products adapted for rolling thin steel products of substantially two-dimensional extension.

The sheet bars are then formed to solid, rolled steel products by annealing at 600–1200° C., preferably 900–1150° C., and rolling. These operations are repeated until the desired compression degree and dimensions are obtained. The compression to single sheet bars, when compared with continuous compression, includes the considerable advantage, that the subsequent treatment, for example sintering, can be divided such, that one press is served by several sintering furnaces, etc. For a continuous strand, the entire material flow from the mill must be handled by one furnace. In view of the time needed for the sintering process and the carbon-oxide reaction occurring during this process, the sintering furnace must have considerable dimensions, if the production rate should be high.

The annealing is preferably carried out in a reducing protective gas atmosphere which may contain carburizing gases, for example carbon monoxide and/or methane. For rendering possible the adjustment of the carbon content in the final product, it is of advantage to be able to control the composition of the protective gas atmosphere.

The invention is illustrated by way of an example in the following description, reference being had to the accompanying drawing showing a flow-sheet of an embodiment of the invention.

The iron ore concentrate used had the following analysis values.

| Chemical composition: | Percent |
|---|---|
| $Fe_{total}$ | 72.0 |
| $SiO_2$ | 0.11 |
| CaO | 0.02 |
| MgO | 0.07 |
| MnO | 0.12 |
| $TiO_2$ | 0.07 |
| $Al_2O_3$ | 0.10 |
| $V_2O_5$ | 0.27 |
| $P_2O_5$ | 0.021 |
| S | 0.003 |

The concentrate was reduced to sponge iron according to the Höganäs-process. The sponge iron tubes obtained were cleaned. The sponge iron was crushed, coarse-ground and pulverized in a desintegrator, whereafter the material was subjected to dry magnetic separation. These steps are represented by the areas **1***a*, **1***b*, **1***c*, and **1***d* on the drawing. The iron powder had the following chemical composition.

| Chemical composition: | Percent |
|---|---|
| $Fe_{total}$ | 98.8 |
| $Fe_{met}$ | 97.2 |
| $SiO_2$ | 0.11 |
| CaO | 0.06 |
| MgO | 0.08 |
| $TiO_2$ | 0.06 |
| $Al_2O_3$ | 0.1 |
| MnO | 0.17 |
| $V_2O_5$ | 0.27 |
| C | 0.36 |
| S | 0.004 |
| $P_2O_5$ | 0.018 |

The concentrate included less than 0.2% rock, exclusive of lattice-bound maganese and vanadium.

The iron powder, after magnetic extreme concentration, was then brought to a press **2** and subjected to a pressure of about 1000 kg./cm$^2$, so that its density was

$\geqq 4$. At this density, the sheet bars could be handled satisfactorily.

The sintering as well as the substantial after-reduction were carried out in furnace **3**. The sintering comprised heat treatment in protective gas at relatively high temperature, in order to impart to the sheet bars such a strength, that they would withstand subsequent rolling without crack formation. A further object was to remove the substantial part of iron oxides contained in the pressed iron powder sheet bars by reaction with the carbon content also contained in the sheet bars.

The iron powder employed contained 1.1% FeO, 0.4% $F_2O_3$, and 0.36% C. The carbon-oxygen reaction commenced at about 600° C., but with a relatively low velocity. At 1000–1100° C., however, the reaction velocity was relatively high. The reaction velocity depends partially on the density of the sheet bars, in such a manner, that higher density renders a more rapid and complete reaction. The reaction was substantially not dependent on which protective gas atmosphere was used. During a furnace treatment of 15 minutes at 1050° C., the carbon content in entirely inactive argon could be reduced to 0.16% and the oxygen content (counted as FeO) to 0.4%. Experiments have proved, that mixtures containing CO and methane had an advantageous effect on the after-reduction.

When applying a protective gas of the composition as follows.

| Chemical composition: | Percent |
|---|---|
| CO | $\leqq 5$ |
| $H_2$ | 15 |
| $N_2$ | 80 |

the C-content, for example, in the sintered sheet bars after a seven minute treatment at 1050° C. was 0.04% and the FeO-content 0.19%. By adjusting the CO and/or methane content in the protective gas, it was possible to control the C-content in the final products.

The density of the sintered sheet bars was slightly above 4, and the porosity about 45%. For obtaining a dense and crack-free product, the porous sheet bars were cold rolled. This type of rolling is called compression rolling. The tendency of crack formation was dependent on the tensile strength and extension properties of the sheet bars, which properties in their turn depend on the density, compression pressure and sintering temperature. The risk of crack formation depends further on the relation between the thickness of the sheet bars and the roll diameter, in such a manner, that when this relation is small, i.e., with thin sheet bars and/or great roll diameter, the risk of cracks is small, even when the reduction chosen is considerable. Referring to the data which are actual in this example, namely: sheet bar thickness=5 mm., density=4, sintering temperature=1050° C. and sintering time=10 minutes, a roll diameter of 700–900 mm. is suitable in rolling mill **4** at a reduction of about 50%. When during some tests the sheet bars were compressed to 2.6 mm. in one pass, i.e., a reduction of 48%, no crack formation was observed. The density increased from 4 to 7.1 g./cm.$^3$. The lateral spread was extremely low. The rolling speed was low, about 0.5 m./sec.

After the compression rolling in mill **4**, an intermediate annealing was carried out in furnace **5**, in order to increase the strength of the material by re-crystallization and sintering for the subsequent cold rolling in mill **6**. The preferable temperature for the intermediate annealing depends on the conditions applied in the foregoing compression rolling. A temperature of 840° C. was found sufficient.

In mill **6**, three cold passes (17, 16 and 16%) were made.

In many cases the thin sheet is desired to be delivered in strips. For rendering this possible according to the described embodiment of the invention, the rolled billets must be welded together. This was performed in welding set **7**. In order to prevent porosity variation in the weld, the welding was carired out after the material was almost dense. The welding was followed by a heat treatment in furnace **8**.

The rolling of the 1.5 mm. thick welded sheets to a cold rolled product with a thickness of 0.8 mm. is preferably carried out by a series of passes with the reductions 21, 19 and 21%. This was made in mill **9**. After the cold rolling, dead annealing was performed in furnace **10** at about 700° C. for about four hours at a relatively slow cooling. The said annealing was followed by temper rolling with a reduction of 1–3% in mill **11** with large roll diameters.

What we claim is:

1. Process for the production of rolled steel products which comprises forming a ground sponge iron powder having a substantial content of iron oxide the bulk of which is exposed at the surfaces of the powder particles, adjusting the carbon content of said iron powder to the stoichiometric equivalent of the iron oxide content thereof by the addition of a member selected from the group consisting of pig iron and cementite, cold pressing said powder to sheet bars having a density of at least 4 g./cm.$^3$, sintering said bars at a temperature of 600–1200° C. whereby the oxygen and carbon contents of the bars are substantially reduced, compression rolling the sintered bars to a density of at least about 7 gm./cm.$^3$, annealing the compressed rolled bars and cold rolling the annealed bars.

2. Process as defined in claim 1 in which the sintering is carried out at a temperature within the range from 900 to 1150° C. in a non-oxidizing gas atmosphere.

3. Process as defined in claim 2 in which the gas atmosphere is reducing.

4. Process as defined in claim 1 in which the compression is effected by cold rolling.

5. Process as defined in claim 1 in which at least a part of the carbon content of the iron powder is provided by the addition of cementite.

6. Process as defined in claim 1 in which the sintering is carried out under a protective carburizing gas.

7. Process as defined in claim 6 in which the protective carburizing gas is a member selected from the group consisting of carbon monoxide and methane.

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