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[54] **FERROSILICON ALLOY**

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[58] **Field of Search**........... 75/0.5 BA, 0.5 B, 0.5 C, 75/123 L, 125

[56] **References Cited**

UNITED STATES PATENTS

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[57] **ABSTRACT**

Ferrosilicon alloy in powder form consisting of smooth, spheroidally shaped particles and having a density of more than 7 g/cc. The alloy contains more particularly between 8 and 15 weight percent of silicon, between 0.5 and 5 weight percent of nickel, between 1.4 and 5 weight percent of copper and between 0.3 and 2.5 weight percent of phosphorus as an additional ingredient.

3 Claims, No Drawings

FERROSILICON ALLOY

A pulverulent ferrosilicon alloy which consists of smooth and spheroidal particles, has a density of more than 7 g/cubic centimeter and is used particularly for the preparation of heavy pulps for the float-sink dressing of minerals, has already been described in German Pat. No. 1 212 733. The alloy contains more particularly between 8 and 15 weight percent of silicon, between 0.5 and 5 weight percent of nickel, between 1.4 and 5 weight percent of copper, the balance being substantially iron. As reported in German Pat. No. 1 246 474, use can be made of pulverulent ferrosilicon for packing dummy projectiles to be fired from a gun.

To be suitable for such use, it is an important requirement for the ferrosilicon powder to be extremely corrosion-proof. This, however, is a specification which is not fully met by conventional ferrosilicon powders alloyed with copper and nickel. Of prime importance is the resistance to corrosion of powdered ferrosilicon, particularly in those cases in which use is made thereof as a packing material in dummy projectiles, so-called practice ammunition, or as a reliable recoil-compensating material, for example in armor-piercing shells. Failing this, the powder tends to agglomerate, which is highly hazardous, as the powder then naturally ceases to disintegrate immediately after the shell leaves the barrel from which it is fired.

We have now unexpectedly discovered that known Fe/Si/Cu/Ni-alloys can be further alloyed with certain proportions of phosphorus to give a considerably more corrosion-proof ferrosilicon powder, of which the further properties vital to certain uses, such as magnetism, resistance to abrasion, viscosity of a heavy pulp made therefrom, remain unaffected. Equally unaffected remains the smooth and spheroidal, preferably spherical, shape of the individual ferrosilicon powder particles.

The increase in weight of an alloy powder, caused by rust, is an index of the alloy's resistance to corrosion. The weight of the phosphorus-containing alloy of the present invention has been found to be increased at a rate which is merely 1/30 to 1/40 of the increase in weight determined for known alloys which are substantially free from phosphorus.

The present invention provides more particularly a pulverulent ferrosilicon alloy consisting of smooth, spheroidal particles, having a density of more than 7 g/cubic centimeter and containing between 8 and 15 weight percent silicon, between 0.5 and 5 weight percent of nickel and between 1.4 and 5 weight percent of copper, the said alloy containing between 0.3 and 2.5 weight percent, preferably between 1 and 1.5 weight percent, of phosphorus as an additional ingredient. As a further ingredient, the alloy may contain between 0.02 and 2 weight percent of carbon. The ferrosilicon alloy of the present invention can be used, for example, as heavy medium in heavy pulps for the float-sink dressing of minerals, or as packing material in dummy projectiles to be fired from a gun, or in practice ammunition.

The alloys of the present invention can be made by melting iron, copper, nickel, quartz gravel, carbon and ferrophosphorus in an electrothermal reduction furnace, or by melting iron, copper, nickel, ferrosilicon and ferrophosphorus in an induction furnace, at temperatures between 1,200° and 1,650°C, and atomizing the resulting melt in known manner under pressures between 2 and 30 atmospheres absolute using water, steam or air as the atomization-inducing agent. The resulting finely divided and fused droplets are chilled in water, subjected to preliminary dehydration, dried and sieved. The powder particles so made substantially have a compact, smooth, spheroidal, drop-shaped or elongated surface. The alloy powder particles have a size substantially between 0.001 and 0.4 mm, the particle size distribution being very regular. It is therefore possible for the screen analysis curves to be plotted, practically as a straight line, in the Rosin-Rammler diagram.

The alloy of the present invention contains copper in a proportion above the limit of solubility of copper in α-iron. As taught by M. Hansen, Constitution of Binary Alloys (McGraw Hill Book Company, New York 1958), the limit of solubility is at 850°C, for a 1.4 weight percent proportion of copper. In the dissolved state, copper and iron are completely soluble in one another. Only upon solidification occurs the separation into two phases, copper being first separated from the γ-modification and later from the α-modification of iron. By the atomization technique used, it is possible for the copper to be retained in the dissolved state in the iron-silicon alloy. On chilling the melt, the state of dissolution is extensively "congealed" in the fused phase. The copper-containing alloy of the present invention cannot simply be made by pouring the melt into moulds and allowing the melt to gradually cool therein, as this would inevitably result in the precipitation of copper. It is, however, possible for the alloy of the present invention to be produced in finely divided form by the steps comprising pouring the alloy melt into moulds, allowing the melt to cool and solidify therein, grinding the solidified material and reducing it to powder, and passing the resulting copper-containing ferrosilicon powder in conventional manner, if desired under pressure and with the use of an atomization inducing agent, through a heated zone, which may be a flame zone, for example.

On being passed therethrough, care should be taken to ensure that the particles are melted round at least superficially. In addition to this, the particles should be allowed to remain in the heating zone for the period of time necessary to ensure dissolution of the copper therein, at temperatures above 850°C. This state is "congealed" in a following cooling and chilling zone.

Heretofore, it has been necessary for phosphorus-free ferrosilicon alloys containing between 8 and 15 weight percent of silicon, such as those described in the Patent first referred to hereinabove, to be produced in costly manner in an induction furnace so as to ensure a minor concentration of carbon, e.g., 0.3 weight percent, therein. This in view of the fact that the resistance to corrosion of these alloys is known to decrease as the carbon content increases. With this in mind, it is all the more an important and unexpected result that the phosphorus-containing ferrosilicon alloy of the present invention, which has up to 2 weight percent of carbon therein, has an unimpaired resistance to corrosion. This means in other words that it is possible for the iron/-silicon/phosphorus alloy to be produced much more economically, in known manner, in an electrothermal reduction furnace which yields alloys having between 1 and 2 weight percent of carbon therein.

In addition to carbon, the iron/copper/nickel/-silicon/phosphorus-alloy may contain customary commercial contaminants including, for example, manganese, aluminum, titanium, chromium, molybdenum, vanadium or sulfur in maximum proportions of altogether 3 weight percent.

In the following Examples, the rust index was identified. To this end, a porcelain dish filled with 20 g of pulverulent alloy and 5 milliliters (ml) distilled water was placed in a drying cabinet, which had a temperature of 75°C, and allowed to remain therein over 75 minutes. Following a cooling period of 25 minutes in each particular case, the above impregnation and vaporization procedures were repeated a further 3 times and the increase in weight (%) was identified.

EXAMPLE 1:

780 kg of iron turnings (shovel grade), 350 kg of quartz-gravel (diameter between 5 and 45 mm), 175 kg of coke (diameter between 60 and 100 mm), 38 kg of waste copper, 38 kg of waste nickel and 75 kg of ferrophosphorus, which contained 20 weight percent of phosphorus (fist size) were melted in an electrothermal reduction furnace and the resulting melt, which had a temperature of 1,550°C, was delivered to an atomization means. The melt was atomized through an annular slit nozzle with steam under a pressure of 12 atmospheres (gauge). The resulting powder was collected in water. Following dehydration and drying, the ferrosilicon powder so made (referred to hereinafter as product B) was tested in the laboratory to determine its rust index and found to have a very good resistance to corrosion. A comparative test was made with product A. This was atomized ferrosilicon which was prepared in analogous manner but was free from phosphorus.

PRODUCT:	A	B
Pycnometer density (g/ml)	7.14	7.18
Apparent density (g/ml)	3.80	3.94
Rust index increase in weight in %	1.50	0.04
Si (weight %)	12.10	12.20
Cu (weight %)	3.60	3.50
Ni (weight %)	3.70	3.60
P (weight %)	0.05	1.40
C (weight %)	1.21	1.20

the balance being iron and customary commerical impurities.

Particle size distribution in starting material in weight %:

> 0.100 mm	4.8	5.0
between 0.063 and 0.100 mm	10.5	10.5
< 0.063 mm	84.7	84.5

EXAMPLE 2:

780 kg of iron scrap, 180 kg of ferrosilicon, which contained 75 weight percent of Si, 38 kg of waste copper, 38 kg of waste nickel and 75 kg of ferrophosphorus, which contained 20 weight percent of phosphorus, were melted in an induction furnace (mains frequency crucible furnace). The resulting melt was atomized under conditions the same as those reported in Example 1 and tested in the laboratory (Product D). Comparative test C was made with an atomized ferrosilicon alloy which was prepared in analogous manner but was free from phosphorus.

PRODUCT:	C	D
Pycnometer density (g/ml)	7.17	7.21
Apparent density (g/ml)	3.81	3.90
Rust index increase in weight in %	1.36	0.03
Si (weight %)	12.40	12.30
Cu (weight %)	3.70	3.60
Ni (weight %)	3.80	3.70
P (weight %)	0.05	1.24
C (weight %)	0.20	0.20

the balance being iron and customary commercial impurities.

Particle size distribution in starting material in weight %:

> 0.100 mm	5.4	5.2
between 0.063 and 0.100 mm	10.6	10.5
< 0.100 mm	84.0	84.3

We claim:

1. A ferrosilicon alloy in powder form consisting of smooth, spheroidally shaped particles, having a density of more than 7 g/cubic centimeter, and consisting essentially of between 8 and 15 weight percent of silicon, between 0.5 and 5 weight percent of nickel, between 1.4 and 5 weight percent of copper, between 0.3 and 2.5 weight percent of phosphorus and between 0 and 2 weight percent of carbon, the balance being iron.

2. The ferrosilicon alloy as claimed in claim **1**, silicon alloy containing between 1 and 1.5 weight percent of phosphorus.

3. The ferrosilicon alloy as claimed in claim **1**, containing between 0.02 and 2 weight percent of carbon.

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