

1

3,243,288

FERROSILICON-ALLOY

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It is old to prepare ferrosilicon alloys in powder form by granulating, spraying or atomizing a ferrosilicon melt with steam, air or water. Atomized ferrosilicon which is prepared for example by atomizing molten ferrosilicon, possesses a uniform, smooth and round surface. (U.S. Patent 2,774,734).

More especially, such atomized ferrosilicon can be prepared for example by the process described in U.S. Patent 2,878,518.

This patent describes a process for making ferrosilicon grains having a smooth surface and a globular form wherein a ferrosilicon melt containing 10–25% silicon is atomized with steam, air or nitrogen, the Al-content in the melt during atomization being adjusted to a value within the limits of 0.08 to 0.5%, preferably 0.1 to 0.3%. The atomization by means of gaseous or vaporous media is advantageously carried out under a pressure of about 12 to 13 atmospheres, the ferrosilicon melt having a temperature of between about 1200 and about 1600° C. The necessary Al-content of the melt is adjusted by adding a corresponding amount of quartz when the Al-content is too high, or by adding a corresponding amount of aluminum when the Al-content is too low. Thus, for example, the aluminum contained in the melt may first completely be removed by introducing silicon dioxide in the form of rock quartz, gravel, quartz sand or silicates rich in silicon dioxide, and the necessary amount of aluminum may then be added in the form of metallic aluminum or an aluminum alloy. Atomized alloys which contain 12 to 18% by weight silicon are used in ore dressing for making heavy pulps for the floating-sinking process.

Ferrosilicon alloys containing, for example 45% Si, are used in powder form for the manufacture of sheathing compositions for the manufacture of extruded types of welding electrodes.

For use in ore dressing, the ferrosilicon alloys must be, for example, resistant to corrosion and abrasion, and they must be magnetic.

In alloys in powder form which have as small a grain size as up to a diameter of 250 μ , the surface is strongly enlarged. In order to be stable to aqueous solutions having a pH-value below 7.0 the FeSi grains should contain more than 12% by weight silicon. The result thereof is a unit weight number (relative weight=weight of material:weight of water having the same volume at 4° C.) of about 6.8 for pulverized FeSi.

It is also known that in preparing iron-silicon alloys as so-called cast silicon the corrosion resistance of these alloys to acid media can be considerably improved by adding about 0.65% manganese to FeSi-alloys containing about 15% by weight Si. It has also been proposed in the literature to add 0.3% to 1% copper.

Still further, it has already been described that by using ferrosilicon powder prepared by atomization having a unit weight number of about 6.8, a pulp with a unit weight number of 3.9 can be obtained in ore dressing by adjusting the Al-content in the manner described above to a value between 0.08 and 0.5% with the resultant formation of ferrosilicon particles having a smooth and globular surface.

2

In many cases, it may, however, be desirable to prepare pulps having higher unit weights, but these can only be obtained with the use of FeSi powders having a unit weight number above 7. Such higher unit weight number must not be reached, however, to the detriment of magnetism, high corrosion resistance and resistance to abrasion. It is therefore impossible to increase the unit weight number solely by reducing the Si-content which would impair the corrosion resistance. The above mentioned improvement in corrosion resistance of the FeSi alloys by incorporating therewith manganese becomes only effective if the Si-content does not fall below 12% by weight. The unit weight number of the FeSi-alloy could be increased for the same Si-content by incorporating therewith very large amounts of nickel which has a unit weight number of 8.9. Such incorporation of nickel would, however, impair or even annul the magnetic properties of the FeSi-powder notwithstanding that pure nickel itself is strongly ferromagnetic. Moreover, the price of the product would be considerably enhanced.

The present invention unexpectedly provides a ferrosilicon alloy in powder form having grains with a smooth and globular form which complies with all the aforesaid requirements, the alloy containing 8 to 15% by weight silicon, 0.5 to 5% by weight nickel and 1.4 to 25% by weight copper.

The ferrosilicon alloys of this invention have a unit weight number of 7.1 to 7.4, at most 5% by weight of the alloy being constituted by grains having a size of 200 to 250 μ and about 50% by weight of the alloy being constituted by grains having a size of smaller than 60 μ . They can therefore be used in floating-sinking plants for ore dressing, the heavy pulps having unit weight numbers of about 4.2. The ferrosilicon alloys according to this invention are further distinguished from the alloys customarily used by their higher degree of magnetization, smaller residual magnetization, and greater abrasion resistance.

These properties can be further improved by incorporating with the alloy as additional alloy components 0.8 to 3.0% by weight manganese and/or 0.08 to 0.5% by weight aluminum.

The ferrosilicon alloys according to this invention are prepared in powder form by allowing the alloy melt to solidify, that is to say by spraying or atomizing or granulating a melt having the above composition with steam, air or water.

The alloy according to the present invention contains nickel to an extent of more than 0.5% and in addition thereto copper to an extent outside the limit of solubility of copper in α -iron. According to M. Hansen, "Constitution of Binary Alloys" (McGraw-Hill Book Company, New York, 1958) this limit of solubility is situated at 1.4% by weight of copper at 850° C. In the liquid state, copper and iron are completely soluble in one another; the separation into two phases occurs not until solidification, for example with less than 10% copper, with the separation of copper from the γ -iron and then from the α -modification. The technique used for atomization then permits to maintain the copper in solution in the ferrosilicon alloy. On chilling the melt, the state of dissolution of the molten phase is substantially frozen.

The copper-containing alloy according to this invention cannot be prepared by casting the melt into molds, because the separation of copper would be inevitable during slow cooling.

The alloy can be prepared in finely divided form and preferably with the use of less than 10% copper by first pouring the molten alloy into molds, permitting it to cool therein and then grinding the solidified alloy and thus converting it into powder form. The FeSi-powder so obtained, which contains less than 10% copper, is then

3

passed through a heating zone, in which the particles must be melted round at least superficially. The FeSi-powder must remain in the heating zone for a period of time sufficient to ensure that the copper contained in the powder dissolves at temperatures above 850° C. This state is then frozen in a following cooling and chilling zone.

The atomization of a molten FeSi-alloy containing less than 12% Si is associated with a reduction of the surface tension with the result that the granular form of the atomized alloy remains no longer globular, and a torn, sputtered grain is obtained, which cannot be used for heavy pulps. The use of copper in conjunction with nickel as alloy components enables the surface tension to be increased again, so that in spite of reduced Si-contents grains having a smooth, rounded-off and almost globular form are obtained by atomization.

The addition of nickel and copper as alloy components in conjunction with the formation of a powder having a smooth surface and containing grains having a rounded-off, globular shape enables as compared with customary alloys, the same if not an improved corrosion resistance to be obtained in the alloys of this invention.

The properties of a FeSi-alloy in powder form which in accordance with this invention contains copper and nickel besides aluminum are illustrated by the following examples, in which two customary FeSi-grades (e.g. No. 1 and 2) are compared with a FeSi-powder grade according to this invention (e.g. No. 3) as regards their magnetic properties and resistance to abrasion:

Alloy constituents	No. 1	No. 2	No. 3
Percent by weight:			
Si	14-16	14-16	8-12
Cu	<0.5	<0.5	1.4-5
Ni	<0.5	<0.5	0.5-5
Al	0.5-3.0	0.08-0.5	0.1-0.3
Unit weight number	6.7	6.7	>7.1

Of alloy quality No. 3 the following grades containing 9.7% Si, 3.6% Cu, 3.2% Ni and 0.1% Al
9.9% Si, 3.9% Cu, 3.5% Ni and 0.11% Al
were tested.

MAGNETIC PROPERTIES

FeSi-powder	Magnetization	Residual magnetization
1.-----	12-17	60-70
2.-----	15-17	60-70
3.-----	16-20	15-30

The test were conducted under identical conditions. For the sake of simplicity comparable nondimensional figures are indicated in the vertical columns (cf. "Zeitschrift für Erzbergbau und Metallhüttenwesen," vol. XIII (1960), pages 477-484, published by Dr. Riederer-Verlag G.m.b.H., Stuttgart). The residual magnetization is, of course, always inferior to the magnetization, although the figures for the residual magnetization do not indicate such fact since they are still associated with a factor. The numerical values indicated cannot therefore be compared with each other in the horizontal line.

As demonstrated above, the alloy composition No. 3 possesses very good magnetic properties and is therefore very suitable for use in floating-sinking processes for preparing heavy pulps. Associated with a good magnetization alloy No. 3 possesses relatively low values for residual magnetism, that is to say it can readily be magnetized and readily demagnetized.

RESISTANCE TO ABRASION

The resistance to abrasion was determined as follows: of the FeSi-alloys No. 1, 2 and 3 the grains having a size of 100 to 150 μ were screened out, ground for 30 minutes

4

in a ball mill, and the grain fractions having a size of less than 100 μ were determined. The test conditions being maintained identical, this method indicates a measure for the resistance to abrasion of the powder grades tested. The proportions of grains having a size greater than 100 μ after the grinding indicates how many grains have not been crushed under such stress, whilst the proportion of grains having a size of less than 100 μ indicates how far the grains have been comminuted.

[Grain size in μ . Proportions in percent]

FeSi powder	Unit weight	>100	75-100	60-75	43-60	<43
1.-----	6.7	50-60	20-25	8-10	3-5	8-10
2.-----	6.7	60-65	18-22	6-8	2-3	2-3
3.-----	7.2	70-80	13-18	3-5	2-3	1-2

The above table shows that the alloy grade No. 3 as used in this invention is especially fast to abrasion.

The present invention relates more especially to a ferrosilicon alloy containing

	Percent by weight
Silicon	8-15
Nickel	0.5-5
Copper	1.4-25

The ferrosilicon alloy may also contain as additional alloy component 0.08 to 0.5% by weight aluminum.

It is especially advantageous to use a ferrosilicon alloy containing

	Percent by weight
Silicon	8-12
Nickel	0.5-5
Copper	1.4-5
Aluminum	0.1-0.3

The ferrosilicon alloy may also contain as a further alloy component 0.8 to 3.0% manganese.

The alloys can be obtained in powder form with particles having a smooth and rounded-off surface, and a unit weight number of more than 7. In this case, the FeSi-alloys in powder form should have the following grain size distribution: about 50% by weight of the alloy should consist of particles having a size of less than 60 μ and at most 5% by weight of the alloy should consist of particles having a size of 200 to 250 μ .

The ferrosilicon particles may be globular, drop-shaped or have an elongated shape. They may consist of atomized ferrosilicon, which is obtained by atomizing molten ferrosilicon, the ferrosilicon melt, which may have been obtained by electrothermal means, being atomized with the aid of water, steam, air or nitrogen under a pressure of about 2 to 1 atmospheres (1 to 12 atmospheres gage) and the ferrosilicon melt having a temperature of about 1200 to about 1600° C. The rounded-off FeSi-particles can also be obtained in finely distributed form from the molten ferrosilicon alloy by directly converting it into powder form on a granulating disc, water being the preferred agent for comminuting the melt and chilling it. The agents used for comminution and/or chilling, which include water, steam, air and nitrogen, are forced, for example, to pass through nozzles under a pressure of about 1 to 20 atmospheres gage.

Still further, the rounded-off FeSi particles can be obtained in finely distributed form from the molten ferrosilicon alloy by directly converting it into powder form on a granulating groove, water and/or air being the preferred agents for comminuting the melt and chilling it. The agents used for comminution and/or chilling which include water, steam, air and nitrogen, are forced, for example, to pass through nozzles under a pressure of about 1 to 20 atmospheres gage.

The FeSi-particles having a smooth and rounded-off surface can also be prepared as follows: solid FeSi-particles containing copper in a proportion of preferably

5

less than 10% weight produced in known manner by grinding are passed in a manner known as such, if desired under pressure and with the aid of an atomizing agent through a heating zone, for example a flame zone, at temperatures above 850° C., the FeSi-particles being melted round at least superficially on passing that zone with dissolution of the copper they contain, and allowed to solidify in a cooling or chilling zone following the heating zone.

The following examples serve to illustrate the invention but they are not intended to limit it thereto.

The examples describe the preparation of a ferrosilicon alloy as used in this invention with the aid of various porcesses which can be used for comminuting the alloy melt.

Example 1

The alloy was melted in an electrical crucible induction furnace but any other appropriate and preferably electrically operated furnace may be used for melting the alloy.

In a mains frequency crucible furnace 900 kg. iron scrap and 150 kg. ferrosilicon containing 74.5% Si were melted. The resulting alloy which contained 10.4% silicon was admixed with 45 kg. solid copper and 40 kg. solid nickel at a temperature of 1420° C. After the nickel and copper were molten, 2 kg. aluminum were added to the melt, i.e. at a moment shortly before the melt was conveyed to the atomizing means. When the aluminum was added at an earlier processing stage the aluminum was rendered inactive by oxidation at the melt surface. The melt was atomized through an annular slit-shaped nozzle with steam under a pressure of 5.5 atmospheres gage. The powder obtained was collected in water. After drying, the grains were investigated under the microscope. They had a smooth and rounded-off surface. The powder so produced had a unit weight number of 7.2. The chemical composition within the alloy grade No. 3 mentioned above was:

	Percent
Si -----	9.9
Cu -----	3.9
Ni -----	3.5
Al -----	0.11

Example 2

A melt as described in Example 1 was admixed in addition to the alloy components copper and nickel mentioned in that example with 30 kg. ferromanganese containing 75% Mn. The resulting melt was further admixed with 2 kg. aluminum shortly before it was conveyed to the comminuting means. In the present example, the annular slit-shaped nozzle was replaced by a conventional granulating disc. The comminuted alloy was chilled in water. Investigation under the microscope after drying indicated that the grains had a smooth and globular surface. The powder obtained had a unit weight number of 7.25, and its composition was similar to the powder obtained in Example 1.

	Percent
Si -----	9.4
Cu -----	3.8
Ni -----	3.4
Mn -----	1.9
Al -----	0.1

Example 3

In a mains frequency crucible furnace 200 kg. FeSi containing 75.6% Si and 780 kg. iron scrap were melted. The resulting melt was admixed with 30 kg. nickel, 20 kg. ferromanganese containing 75% Mn, and 145 kg. copper. Immediately before atomization, the finished alloyed melt was treated with 4 kg. aluminum. The

6

liquid alloy was atomized with air under a pressure of 11.2 atmospheres and a fine powder was obtained. Investigation under the microscope indicated that the particles had a smooth surface and a substantially globular shape. The alloy in powder form had a unit weight number of 7.4 and contained

	Percent
Si -----	12.5
Ni -----	2.5
Cu -----	12.1
Mn -----	1.1
Al -----	0.15

15 We claim:

1. A ferrosilicon alloy containing about 8 to 15% by weight silicon, about 0.5 to 5% by weight nickel, about 1.4 to 25% by weight copper, about 0.08 to 0.5% by weight aluminum and the balance essentially iron, the alloy being in powder form having grains of a smooth and rounded-off surface and having a unit weight number of more than 7.

2. The ferrosilicon alloy as claimed in claim 1 containing 8 to 12% by weight silicon, 0.5 to 5% by weight nickel, 1.4 to 5% by weight copper, 0.1 to 0.3% by weight aluminum and the balance essentially iron.

3. The ferrosilicon alloy as claimed in claim 1 containing about 0.8 to 3.0% by weight manganese as an additional alloy component.

4. The ferrosilicon alloy as claimed in claim 1, wherein about 50% by weight is constituted by grains having a size of less than 60 μ and at most 5% by weight is constituted by grains having a size within the range of 200 to 250 μ .

5. A process for the manufacture of a ferrosilicon alloy comprising atomizing a molten ferrosilicon alloy containing about 8 to 15 per cent by weight silicon, about 0.5 to 5 percent by weight nickel, about 1.4 to 25 percent by weight copper, about 0.08 to 0.5 percent by weight aluminum and the balance essentially iron with at least one substance selected from the group consisting of water, steam, air and nitrogen under a pressure of about 1 to 12 atmospheric gage, the molten ferrosilicon alloy having a temperature between about 1,200 and about 1,600° C.

6. A process for the manufacture of a ferrosilicon alloy comprising directly transforming a molten ferrosilicon alloy containing about 8 to 15 percent by weight silicon, about 0.5 to 5 percent by weight nickel, about 1.4 to 25 percent by weight copper, about 0.08 to 0.5 percent by weight aluminum and the balance essentially iron into powder form on a granulating disc, the resulting powder being constituted by finely distributed rounded-off ferrosilicon particles, the molten ferrosilicon being comminuted and chilled with at least one substance selected from the group consisting of water, steam, air and nitrogen maintained under a pressure within the range of about 1 to 20 atmospheric gage.

7. A process for the manufacture of a ferrosilicon alloy comprising directly transforming a molten ferrosilicon alloy containing about 8 to 15 percent by weight silicon, about 0.5 to 5 percent by weight nickel, about 1.4 to 25 percent by weight copper, about 0.08 to 0.5 percent by weight aluminum and the balance essentially iron into powder form on a granulating groove, the resulting powder being constituted by finely distributed rounded-off ferrosilicon particles, the molten ferrosilicon being comminuted and chilled with at least one substance selected from the group consisting of water, steam, air and nitrogen maintained under a pressure of between about 1 to 20 atmospheric gage.

8. A process for the manufacture of a ferrosilicon alloy comprising passing solid ferrosilicon particles containing about 8 to 15 percent by weight silicon, about 0.5 to 5 percent by weight nickel, about 1.4 to 25 percent by

weight copper, about 0.08 to 0.5 percent by weight aluminum and the balance essentially iron obtained by grinding under pressure and with the aid of an atomizing agent through a heat zone at temperatures of about 850° C., the ferrosilicon particles being melted round at least superficially on passing the heat zone with a dissolution of the copper contained therein and solidifying the particles in a cooling and chilling zone following the heating zone.

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