

PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

A Method of and an Apparatus for Reducing Iron Oxide to Sponge Iron

We, METALLGESELLSCHAFT AKTIENGESELLSCHAFT, of 14, Reuterweg, Frankfurt-on-the-Main, Germany, a body corporate organised under the Laws of Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

- 5 This invention relates to a method of and apparatus for reducing iron oxide in any stage of oxidation, particularly concentrates, to sponge iron by heating previously agglomerated, for instance briquetted or pelletised, iron oxides in a rotary furnace with an excess of reducing agents and by means of burners distributed on the shell of the furnace for supplying a substantial proportion of the necessary heat of reaction.
- 10 It is an object of the invention to eliminate the process of hardening the agglomerates (briquettes or pellets), which has in the past been considered indispensable before the agglomerates are fed for reduction into the rotary furnace, and substantially to enlarge the permissible range of grain sizes both upwards and downwards, which in practice in this type of reduction had been kept within the limits of 6 to 15 mm. diameter (cf. Canadian Patent Specification No. 617,445, and US Patent Specification No. 3,029,141), so that, for instance in the known process of pelletising the concentrates in drums, the return of fines can be greatly reduced, if not rendered wholly superfluous, and finally to produce a particularly light and highly reducible and possibly briquettable green pellet. Owing to their mechanical strength and their micro-porosity agglomerates (pellets) produced and reduced by the present method are particularly suitable for use in blast furnaces, cupola furnaces, open hearth furnaces, electric arc fur-

naces and induction furnaces as well as in oxygen converters.

A report by Kurt Meyer on the production of plastically deformable, moist, so-called green pellets appeared in the periodical "Stahl und Eisen", 1956, on pages 588—595, and 1962 on pages 147 to 154. The present invention is substantially a development of the state of the art therein described. Three methods of hardening have been proposed, namely burning in a shaft kiln, on a travelling grate and in a rotary kiln or on a gas or oil heated sinter chain (ibid. 1962, p 148).

According to the present invention there is provided a method of reducing iron oxide to sponge iron, wherein the iron oxide previously formed into agglomerates, such as briquettes or pellets, is directly introduced as such briquettes or pellets in the moist, plastically deformable state together with an excess of a solid reducing agent into a rotary furnace equipped with angle burners distributed along its shell for adjusting the gas atmosphere inside the furnace, a substantial proportion of the heat of reaction being supplied by the burners and the briquettes or pellets being rapidly heated in the preheating zone of the furnace to a temperature below the level which would be required for burning the pellets hard outside the furnace.

Thus with the present method the hardening of green pellets or similar agglomerates in a rotary kiln as a preliminary to their subsequent reduction is rendered superfluous by utilising the conventional preheating zone in a rotary furnace for directly heating the agglomerates to the temperature of reduction, dispensing with the process of burning the agglomerates until they are hard. Experiments have unexpectedly shown that it is possible to introduce the moist agglomerates or plastically deformable green pellets directly into a reducing rotary furnace provided with

burners distributed over the entire length of the furnace without, as might have been expected, destroying the plastic pellets by the mechanical buffeting which they receive or by the sudden expulsion of water due to the heat. The water content of the agglomerates (green pellets) may even be increased to the limit which the formability of the initial material (concentrate) during pelletisation permits. In highly concentrated iron oxides this may be a water content of 12%. In conjunction with or without this additional water content the moist green pellet may be provided (dusted) with a layer of fuel before or when it is charged into the rotary kiln.

The direct introduction into the rotary kiln for reduction therein of the moist agglomerate or green pellets which have not been predried or preheated gives rise to the formation of a novel type of agglomerate or pellet which, after having been reduced, exhibits a far higher microporosity than a hard-burned pellet and hence a lower apparent density which in order of magnitude is about 1.3 g./cc., although it has a perceptibly higher mechanical strength, has a substantially better degree of reduction and permits a clear increase in throughput (30%) without any change in the grain size of the charged stock. At the same time the exhaust gas temperature falls at the entry end of the rotary furnace from say 700° C. when introducing burnt pellets as heretofore to say 550° C., this being due to the high rate of evaporation of the water. In the Specification of published German Patent Application 1,058,080 (published and issued the 27th May 1959 and now abandoned) it has been proposed to pelletise moist oxides in a rotary drum and then to dry them to increase their mechanical strength, and, in this condition, to introduce them into a rotary furnace in which they are gradually heated to about 1070° C. (cf. the example loc. cit. col. 4, lines 22 to 66). At the end of a four-hour residence in the furnace a hard sponge iron pellet is formed but because of shrinkage its apparent density has gone up from about 2.5 g./cc. to about 3.2 g./cc. This shrinkage and increase in apparent density does not occur in the present method in which the green pellets are heated and burned at a temperature below the temperature level required for burning them into hard pellets.

Whereas in the conventional process of burning the pellets outside the reducing furnace, crystal growth leads to coarsening of the grain and bonding is due to slag formation; neither of these two phenomena occur in the present method which therefore proceeds at a higher rate of reduction and at the same time improves the microporosity of the product.

Moreover, as has been found, the rapidly initiated reduction of the oxides to metallic iron causes the formation of an elastic very

porous metal skin which does not hinder the further penetration of the reducing gases as is the case when the pellets have been previously hardened, but on the contrary assists it because this skin imparts a surprising amount of stability to the pellet whilst at the same time maintaining its original porosity when the water has been expelled, a fact which finds expression in the above noted low density of the pellet of only about 1.3 g./cc.

The agglomerate, i.e. green pellet, which has been reduced by the present method can be much more easily compacted into a briquette with a dense smooth surface than a preburnt pellet and the tendency to rusting is correspondingly much less. Processing by crushing into iron powder is likewise more convenient because the above mentioned crystal structure and the high microporosity assists the size reduction.

Instead of being confined to the above mentioned grain size range of green pellets produced according to the state of the prior art, the green pellets used for performing the present method can be produced within a substantially wider range of grain sizes, for instance between 3 and 25 mm. diameter and even more and introduced into the rotary reducing furnace in the moist state, possibly even with an excess water content, the rotary furnace being equipped with angle burners distributed along its shell, the burner mouths preferably being placed pointing in the axial direction contrary to the direction of flow of the furnace gases.

It is preferred to coat the moist green pellets with a layer of reducing agent for example coke or coal, before they are introduced into the reducing furnace. A portion of the solid fuel required for reduction may also be incorporated in the agglomerates or pellets. Between 10 and 40% of the fuel for reduction may be thus introduced. Both these steps can be readily performed at the entry end of the rotary furnace, for instance by providing a conventional rotary pan with a dusting flange or a conventional rotary drum or a vibrator as a feeder means at the entry of the furnace or projecting into the preheating zone of the rotary furnace. If a rotary drum is used in its interior may be provided with a fixed conveyor screw and means may be provided for increasing the speed of rotation of the drum in relation to than that of the rotary furnace. In all feeder means of such a kind the plastic green pellets which may have been intentionally provided with a high water content must be gently treated and embedded in the solid fuel for reduction is of great assistance during the charging process.

U.S. Patent Specification No. 2,829,042 describes a rotary furnace with an axial arrangement of the mouths of angle burners to point in cocurrent with the furnace gases

and in countercurrent to the charge. In the present method, the position of the angle burners is generally reversed, i.e. they will be placed to operate in countercurrent to the furnace gases. Moreover, the angle burners are not supplied with a preheated gas-air mixture, but operate in the manner of burners used for welding, the angle burners consisting of two coaxial burner pipes of which the outer pipe is used for the controlled admission of compressed air and the inner pipe for the controlled admission of the combustible gas. The furnace atmosphere can thus be controllably adjusted within wide limits. Finally, for instance the burner mouths in the heating zone may be directed vertically to the furnace axis or at an acute angle thereto in order to evaporate the water from the green pellets at as high a rate as possible.

An example of the invention will now be described in greater detail.

In this example a natural or synthetic magnetite in pellet form was used instead of hematite because it was found that the generally more difficultly reducible magnetite can be reduced to a surprisingly high degree by introducing it in the form of green pellets directly into the preheating zone of a rotary furnace.

An iron concentrate (total Fe 69—69.5%, sulphur 0.15—0.2%) which occurs as a natural magnetite was pelletised with water on a pelletising pan into pellets having a diameter between 8 and 25 mm. As a binder 0.5% of bentonite was added. The moist pellets, having a water content of 7%, were charged into a jacket-heated rotary furnace together with coke fines as the reducing agent and dolomite as a desulphurising agent. The length of the furnace was 9 metres, whereas its internal diameter was 0.5 metres. Six jacket burners in the form of angle burners were roughly equidistantly fitted into the furnace shell.

The furnace was heated with town gas and the following moist weights were introduced per hour:—

66 kg. of green pellets	10—25 millimetres
40 kg. of coke fines	0—10 "
3 kg. of dolomite	1—3 "

The pellets were reduced for 4 to 5 hours in the rotary furnace at a temperature of 1100° C., discharged into a cooling drum and cooled therein for one hour to ambient temperature. The sponge iron product was separated dry from the surplus coal and the desulphurising agent by screening and magnetic separation. An analysis of the product gave the following result:—

Total Fe	97.0%
Metal Fe	95.0%
S	0.03%
C	0.05%

In other words, 98% of the ore was reduced to metallic iron, representing a degree of reduction of about 99%. The content of fines in the sponge iron product, that is to say the portion under 8 millimetres, was 35%. In order of magnitude this was therefore equal to the quantity of fines produced when reducing burnt magnetite pellets of the same origin. Since the green pellets were introduced into the rotary furnace in the same way as the burnt pellets, this content of fines must have been due to mechanical wear prior to reduction, whereas the fines content during the reduction of burnt pellets must be explained by disintegration during reduction. The surface of the pellets when discharged was completely smooth and the pellets themselves were very porous. The pore volume, irrespective of grain size, was about 83%. The weight per unit volume of the pellets was correspondingly extremely low and was found to be 1.3 g./cc. The true specific weight was determined at 7.4 g./cc., likewise irrespective of grain size, and this was in conformity with the high degree of reduction of 99%. Despite their low density, the pellets were mechanically stronger than magnetite pellets of like size which had been burnt prior to their reduction. Reduced green pellets of 15 to 20 millimetres diameter did not collapse until a pressure of 56 kg./pellet had been applied, whereas the corresponding strength of previously burnt pellets was about 41 kg./pellet. Reduced green pellets of over 20 millimetres diameter could carry a load of up to 100 kg./pellet before they eventually collapsed.

The sponge iron product thus obtained directly from green pellets could be very easily briquetted. At a pressure of 2.5 tonnes/sq. cm a weight per unit volume of 4.5 g./cc. was obtained. Unlike briquettes made of burnt pellets the surface of the briquettes made of reduced unburnt pellets was completely smooth. The grain boundaries of the incorporated pellets could not be visually detected.

Combined with the favourable briquetting qualities of the pellets was their easy disintegrability. After having been pre-crushed to 2 millimetres in an impact mill they were readily ground down within a very short space of time to under 0.04 millimetres in a rod mill.

In order to enable the invention to be further understood, reference will now be made to the accompanying diagrammatic drawing which illustrates an arrangement and equipment for directly feeding green pellets into a rotary furnace or rather into its preheating zone.

Shown in the top right hand corner of the drawing is a conventional pelletising pan 1 with a dusting flange 2. Green pellets are produced on this pan and are provided for instance with a dusted coat of solid pulverulent

fuel. The resulting green pellets drop in the direction of the arrow 3 directly into a feeder 4 which extends through the head 5 of a rotary furnace 6 and which is shown in the drawing as a vibratory feeder but which may be a rotary drum. A gas-tight flexible seal is provided between the vibrator 4 and the furnace head 5. A solid reducing fuel of conventional grain size is introduced on the right of the extreme end 7 of the feeder so that the green pellets, with or without powder coal, fall into this fuel bed and enter the rotary furnace together therewith. Finally, a desulphurising agent, for example limestone or dolomite, is added immediately in front of the furnace head at 8. The hot exhaust gases, indicated by arrows 9 and 10, pass around the feeder 4 so that drying of the pellets (not shown) begins immediately they are fed into the furnace.

When a rotary drum is used in place of the feeder 4, it is positioned so as to project into the preheating zone of the rotary furnace and means are provided for increasing the speed of revolution of the rotary drum in relation to the speed of revolution of the rotary furnace.

WHAT WE CLAIM IS:—

1). A method of reducing iron oxide to sponge iron, wherein the iron oxide previously formed into agglomerates, such as briquettes or pellets, is directly introduced as such briquettes or pellets in the moist, plastically deformable state together with an excess of a solid reducing agent into a rotary furnace equipped with angle burners distributed along its shell for adjusting the gas atmosphere inside the furnace, a substantial proportion of the heat of reaction being supplied by the burners and the briquettes or pellets being rapidly heated in the preheating zone of the furnace to a temperature below the level which would be required for burning the pellets hard outside the furnace.

2). A method as claimed in Claim 1, wherein the briquettes or pellets are rapidly heated to the reducing temperature of 1100° C.

3). A method as claimed in Claim 1 or 2, wherein the water content of the briquettes or pellets is increased to the extent this is compatible with the briquettes or pellets keeping their shape.

4). A method as claimed in any one of Claims 1 to 3, wherein the briquettes or pellets are surrounded, prior to or whilst being fed into the rotary furnace with a layer of the reducing agent, possibly performed in two stages by first dusting the pellets with pulveru-

lent reducing agent and then embedding the same in granular reducing agent.

5). A method as claimed in any one of Claims 1 to 4, wherein part of the solid fuel used for reduction is already incorporated in the briquettes or pellets.

6). A method as claimed in any one of Claims 1 to 5, wherein the pellets are produced in sizes within the range of 3 to 25 millimetres diameter and thus charged into the rotary furnace.

7). A method as claimed in any one of Claims 1 to 6, wherein the rotary furnace is heated by angle burners resembling welding burners in type, the mouths of the angle burners in the reduction zone pointing in the axial direction in countercurrent to the furnace gases, whereas the mouths of the angle burners in the preheating zone are directed vertically or at an acute angle to the axis of the rotary furnace.

8). A method as claimed in any one of Claims 1 to 7, wherein the briquettes or pellets are produced from concentrates of natural or synthetic magnetite.

9). A method as claimed in any one of Claims 1 to 8, wherein the reduced and cooled pellets are briquetted.

10). A method as claimed in any one of Claims 1 to 8, wherein the reduced pellets are processed into iron powder.

11). A method of reducing iron oxide to sponge iron substantially as hereinbefore described in the foregoing Example and/or with reference to the accompanying drawing.

12). In the production of iron in a blast furnace, the step of feeding the furnace with the product of the method claimed in any preceding Claim.

13). Apparatus for performing the method claimed in any one of Claims 1 to 8 and 11, comprising a rotary reducing furnace equipped with angle burners distributed along its shell for adjusting the gas atmosphere inside the furnace and pelletising equipment provided directly in front of the charging opening of the rotary reducing furnace.

14). Apparatus as claimed in Claim 13, wherein a rotary drum projects into the preheating zone of the rotary furnace, and is associated with means for increasing its speed of revolution in relation to the speed of revolution of the rotary furnace.

15). Apparatus as claimed in Claim 13, wherein a pelletising pan with a dusting is associated with a vibratory feeder at the input end of the rotary furnace, and wherein means are provided for introducing solid reducing agents and desulphurising agents in stages at spatially consecutive points.

fuel. The resulting green pellets drop in the direction of the arrow 3 directly into a feeder 4 which extends through the head 5 of a rotary furnace 6 and which is shown in the drawing as a vibratory feeder but which may be a rotary drum. A gas-tight flexible seal is provided between the vibrator 4 and the furnace head 5. A solid reducing fuel of conventional grain size is introduced on the right of the extreme end 7 of the feeder so that the green pellets, with or without powder coal, fall into this fuel bed and enter the rotary furnace together therewith. Finally, a desulphurising agent, for example limestone or dolomite, is added immediately in front of the furnace head at 8. The hot exhaust gases, indicated by arrows 9 and 10, pass around the feeder 4 so that drying of the pellets (not shown) begins immediately they are fed into the furnace.

When a rotary drum is used in place of the feeder 4, it is positioned so as to project into the preheating zone of the rotary furnace and means are provided for increasing the speed of revolution of the rotary drum in relation to the speed of revolution of the rotary furnace.

WHAT WE CLAIM IS:—

- 1). A method of reducing iron oxide to sponge iron, wherein the iron oxide previously formed into agglomerates, such as briquettes or pellets, is directly introduced as such briquettes or pellets in the moist, plastically deformable state together with an excess of a solid reducing agent, into a rotary furnace equipped with angle burners distributed along its shell for adjusting the gas atmosphere inside the furnace, a substantial proportion of the heat of reaction being supplied by the burners and the briquettes or pellets being rapidly heated in the preheating zone of the furnace to a temperature below the level which would be required for burning the pellets hard outside the furnace.
- 2). A method as claimed in Claim 1, wherein the briquettes or pellets are rapidly heated to the reducing temperature of 1100° C.
- 3). A method as claimed in Claim 1 or 2, wherein the water content of the briquettes or pellets is increased to the extent this is compatible with the briquettes or pellets keeping their shape.
- 4). A method as claimed in any one of Claims 1 to 3, wherein the briquettes or pellets are surrounded, prior to or whilst being fed into the rotary furnace with a layer of the reducing agent, possibly performed in two stages by first dusting the pellets with pulveru-

lent reducing agent and then embedding the same in granular reducing agent.

5). A method as claimed in any one of Claims 1 to 4, wherein part of the solid fuel used for reduction is already incorporated in the briquettes or pellets.

6). A method as claimed in any one of Claims 1 to 5, wherein the pellets are produced in sizes within the range of 3 to 25 millimetres diameter and thus charged into the rotary furnace.

7). A method as claimed in any one of Claims 1 to 6, wherein the rotary furnace is heated by angle burners resembling welding burners in type, the mouths of the angle burners in the reduction zone pointing in the axial direction in countercurrent to the furnace gases, whereas the mouths of the angle burners in the preheating zone are directed vertically or at an acute angle to the axis of the rotary furnace.

8). A method as claimed in any one of Claims 1 to 7, wherein the briquettes or pellets are produced from concentrates of natural or synthetic magnetite.

9). A method as claimed in any one of Claims 1 to 8, wherein the reduced and cooled pellets are briquetted.

10). A method as claimed in any one of Claims 1 to 8, wherein the reduced pellets are processed into iron powder.

11). A method of reducing iron oxide to sponge iron substantially as hereinbefore described in the foregoing Example and/or with reference to the accompanying drawing.

12). In the production of iron in a blast furnace, the step of feeding the furnace with the product of the method claimed in any preceding Claim.

13). Apparatus for performing the method claimed in any one of Claims 1 to 8 and 11, comprising a rotary reducing furnace equipped with angle burners distributed along its shell for adjusting the gas atmosphere inside the furnace and pelletising equipment provided directly in front of the charging opening of the rotary reducing furnace.

14). Apparatus as claimed in Claim 13, wherein a rotary drum projects into the preheating zone of the rotary furnace, and is associated with means for increasing its speed of revolution in relation to the speed of revolution of the rotary furnace.

15). Apparatus as claimed in Claim 13, wherein a pelletising pan with a dusting is associated with a vibratory feeder at the input end of the rotary furnace, and wherein means are provided for introducing solid reducing agents and desulphurising agents in stages at spatially consecutive points.



16). Apparatus for reducing iron oxide to sponge iron as claimed in claim 13 and substantially as hereinbefore described with reference to the accompanying drawing.

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