Application Accepted and Amendments
Allowed 28-11-84

Commonwealth of Australia 558346

Patents Act 1952

Application for a Standard Patent

Fried. Krupp Gesellschaft mit Beschränkter Haftung a company
organized and existing under the laws of German Federal Republic
of Altendorfer Strasse 103 D-4300 Essen 1 German Federal Republic

hereby apply for the grant of a Standard Patent for an
invention entitled

Process for the Reduction of Oxidic Iron Ores in a Rotary Tubular Kiln

which is described in the accompanying complete specification.

This application is made under the provision of Part
XVI of the Patents Act 1952 and is based on an application
for a patent or similar protection made

in German Federal Republic on 9 September 1983

(No. P 33 32 556.1)

Our address for service is: F.B. RICE & Co.,
28A Montague Street,
Balmain, NSW 2041

Dated this 17th day of August 1983.

Fried. Krupp Gesellschaft mit
Beschränkter Haftung

By - Patent Attorney

To: The Commissioner of Patents

F.B. RICE & Co.,
Patent Attorneys,
Sydney
COMMONWEALTH OF AUSTRALIA
Patents Act 1952

DECLARATION IN SUPPORT OF AN APPLICATION OR A CONVENTION APPLICATION FOR A PATENT OR PATENT-OF-ADDITION

In support of the Convention Application made by
Fried. Krupp Gesellschaft mit beschränkter Haftung

for a patent for an invention entitled:

Process for the reduction of oxidic iron ores in a rotary tubular kiln
We, Walter Dehmer, Director, and Ludger Frieling, Procurist, both of and care of the applicant company do solemnly and sincerely declare as follows:

*“(1) I am the applicant for the patent application.

*(2) We are authorized by the applicant for the patent application to make this declaration on its behalf.

*(3) The basic application(s) as defined by section 141 or 142 of the Act was were made in German Federal Republic on 9th September 1983 by Fried. Krupp Gesellschaft mit beschränkter Haftung.

*(4) The basic application(s) referred to in paragraph 2 of this Declaration is were the first application(s) made in a Convention country in respect of the invention.

Declared at Essen, this 26th day of June 1984

Fried. Krupp
Gesellschaft mit beschränkter Haftung

To: The Commissioner of Patents, Commonwealth of Australia.

This Form is suitable for any type of Patent Application. No legalisation required.

1. Process for the reduction of oxidic iron ores by means of solid high volatile reductants in a rotary tubular kiln in which oxygen-containing gases or oxygen are introduced at localities distributed over the length of the kiln, at least part of the reductants being so introduced from the discharge end of the kiln as to be distributed over a substantial region of the kiln charge bed, and any balance of the reductants as well as the oxidic iron ores and additives being fed at the feed end of the kiln, wherein at least 60% of the solid reductants, excluding the recycle char are introduced from the discharge end and contain not more than 20% of the fines components of particle size less than 3 mm of the total reductants.
7. Process for the reduction of oxidic iron ores by means of solid high volatile reductants in a rotary tubular kiln in which oxygen-containing gases or oxygen are introduced at localities distributed over the length of the kiln, at least part of the reductants being so introduced from the discharge end of the kiln as to be distributed over a substantial region of the kiln charge bed, and any balance of the reductants as well as the oxidic iron ores and additives being fed at the feed end of the kiln, wherein at least 60% of the solid reductants, excluding the recycle char are introduced from the discharge end in two portions, a major portion substantially free of fines smaller than 3 mm which is distributed over a kiln length region from 20% upwards measured from the discharge end and a lesser portion containing sufficient such fines for covering with their heat of combustion by immediate combustion the thermal deficiency prevailing near the discharge which end of the kiln is distributed over the lowermost 20% of the kiln length, the balance of the reductants, including the balance of fines in the reductants being introduced from the feed end as part of the kiln charge bed.
Name of Applicant: FRIED. KRUPP GESELLSCHAFT MIT BESCHRANKTER HAFTUNG

Address of Applicant: Altendorfer Strasse 103, D-4300 Essen 1
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Complete Specification for the invention entitled:

PROCESS FOR THE REDUCTION OF OXIDIC IRON ORES IN A ROTARY TUBULAR KILN

The following statement is a full description of this invention including the best method of performing it known to us:

4. Process according to claim 3, wherein the reductants introduced from the discharge end are distributed over the lowermost section of the kiln.
The invention relates to a process for the reduction of oxidic iron ores by means of solid high volatile reductants in a rotary tubular kiln in which oxygen-containing gases or oxygen are introduced at localities distributed over the length of the kiln, e.g. by way of appropriately distributed and regulated shell nozzles, at least part of the reductants being so introduced from the discharge end of the kiln as to be distributed over a substantial region of the kiln charge bed, and any balance of the reductants as well as the oxidic iron ores and additives being fed at the feed end of the kiln, e.g. jointly.

In the known processes of this type in which iron ores are reduced in lumpy or pellet form in a rotary tubular kiln to form sponge iron, a mixture of iron ores, coal, crude dolomite or limestone serving as desulphurising agent and excess carbon recovered from the process are fed into the rotary kiln mounted at an incline. The mixture of solids is heated by hot kiln gases to a temperature above 900 °C to a maximum of 1240 °C. Such a process is known for example from US-PS 3 890 138.
In the known processes the energy required for heating the solids, the heat requirements of the endothermal reaction and for covering losses is generated partly by the post-combustion of carbon monoxide which is formed by means of air oxygen introduced over the length of the kiln.

It is typical for all such processes that the temperature difference between the hot gases in the open kiln space and the kiln charge amounts to 100 - 150 °C over a major part of the kiln length. It is moreover typical for all direct reduction processes conducted in a rotary tubular kiln that in the lower kiln region where the reduction has been completed already substantially only little carbon monoxide is liberated by the charge. This small amount of carbon monoxide is insufficient to keep by its post-combustion the temperature in that kiln region sufficiently high for a final metallisation of more than 90% (metallisation = metallic iron content/total iron content). In these processes the thermal energy additionally required in the discharge region of the rotary kiln is therefore introduced by combustion of oil, gas or coal.

The rate at which the reaction proceeds, and accordingly the amount of sponge iron produced per unit of kiln volume increases as the temperature of the solids mixture in the kiln is increased. Accordingly, for purposes of economical operation the material temperature is set as high
as possible. However, in those processes in which major proportions of small sized high volatile coals are blown into the kiln from the discharge end this frequently results in operating breakdowns due to the adherence of molten or caking solids particles to the inner kiln periphery. These deposit buildups can result in substantial interference with the material flow in the kiln. In various commercial plants they resulted in such reductions of the free kiln cross section that production had to be stopped in order to strip off these deposits from the kiln.

There accordingly exists a need for a process of the type defined in the introduction in which in spite of heating with cheap bituminous coal the formation of deposits in the rotary tubular kiln is avoided substantially.

In accordance with the invention a process as set out in the opening paragraph is provided wherein at least 60% of the solid reductants, excluding the recycle char are introduced from the discharge end and contain not more than 20% of the fines components of particle size less than 3 mm of the total reductants.

According to a further aspect of the invention a process as set out in the opening paragraph is provided, wherein at least 60% of the solid reductants, excluding the recycle char are introduced from the discharge end in two portions,
a major portion substantially free of fines smaller than 3 mm which is distributed over a kiln length region from 20%. upwards measured from the discharge end and a lesser portion containing sufficient such fines for covering with their heat of combustion by immediate combustion the thermal deficiency prevailing near the discharge end of which the kiln is distributed over the lowermost 20% of the kiln length, the balance of the reductants, including the balance of fines in the reductants being introduced from the feed end as part of the kiln charge bed.

It was found surprisingly that the process according to the invention permitted deposit formation to be avoided virtually completely, an advantage which is normally attained only by heating the kiln entirely with gas, which, however, as a rule increases the cost of the process substantially.

A further advantage resides in the fact that high volatile coals of various types, e.g. even brown coal can be used. High volatile fuels in particular coals are considered to denote fuels, the volatile content of which amounts to at least 20% by mass.

Advantageous embodiments of the new process are reflected in the claims, the contents of which are to be considered an integral part of the present disclosure.

The amounts of reductants referred to in the claims relate throughout to freshly added reductant (fresh coal) only, the recycled pyrolysed reductant residues (recycled char) are thus not included.
The process according to the invention will be further explained with reference to the following working example. Using that example in the operation of a large scale plant for sponge iron production, it was possible to demonstrate that deposit formation in conducting the process was avoided entirely. The kiln was of the type commercially available from the present applicant, an example of which is in commercial operation at Dunswart Steel near Benoni, South Africa.

Coal having a volatile content of more than 25% was screened at 3 mm. The coarse coal fraction having particle sizes from 3 - 35 mm was charged with a pneumatic injection device from the discharge end into the kiln. The injection was so carried out, more particularly by regulating the injection airflow that the coal, measured from the discharge end was distributed uniformly over the region from about 20% to about 60% of the kiln length. The coal pyrolysis gases liberated by the heating up of the coarse coal mixed with the charge was combusted by means of atmospheric
oxygen introduced through shell nozzles. The post-combustion of these gaseous energy sources provided the predominant portion (about 85%) of the additional thermal energy required in the respective kiln regions and which was not available from the post-combustion of carbon monoxide. The rotary tubular kiln has a shell diameter of 4.6 m and a length of 74 m.

A small portion of coal having particle sizes 0 - 35 mm, i.e. non-screened coal was pneumatically injected through a second injection device into and spread over a region of 0 - 15 m distance from the discharge end, i.e. 0 - 20% of the kiln length. The combustion of the fine coal content, less than 3 mm supplied the remaining approximately 15% of the required additional thermal energy. The screened off coal fines of particle sizes of less than 3 mm were fed with the remaining coal, i.e. the balance of the total reductant introduced jointly with the air, the desulphurising agent and the recycle char at the feed end, i.e. the upper kiln end.

The specific parameters of the process according to the invention were determined as follows:

Altogether the following amounts of material based on 1 t of sponge iron produced were charged:

1.43 t ore of 66% Fe and a particle size of 5 - 25 mm
0.048 t crude dolomite having a particle size of 1 - 4 mm

0.12 t recycled char, particle size: 1.6 - 10 mm

Of the total amount of coal of 0.593 t/t of sponge iron the following amounts were fed with the ore, crude dolomite and recycle char:

0.157 t coal/t of sponge iron with a particle size of 0 - 35 mm.

The amounts injected into the kiln from the discharge end were:

0.436 t coal/t sponge iron

This amount was composed of

0.377 t coal/t sponge iron having particles sizes from 3 - 35 mm and

0.059 t coal/t sponge iron having particle sizes of 0 - 3 mm.

The sponge iron produced had 92% metallisation.

The coal, having a lower thermal value of 27 MJ/kg had the following composition:
solid carbon 59.0%
Volatile components 30.0%
Ash 11.0%
Sulphur 0.9%
Water 4.0%

and the following elemental analysis:

C: 74.8%
H: 4.6%
O: 7.7%
N: 1.0%
S: 0.9%

From the molar ratio of hydrogen to volatile carbonaceous components, it was calculated that the volatile hydrocarbons of the coal were present predominantly in the form of CH₄. Applying the known thermal value of CH₄ = 35.8 MJ/Nm³, it is possible to derive approximately the following amount of heat from the combustion of the volatile components of this coal:

9.23 MJ/kg coal.

From a thermal balance compiled for the rotary kiln plant operating with the abovementioned amounts of charge material for producing sponge iron, the following specific energy requirements per ton of sponge iron produced are apparent:
- Covering the endothermal reduction reaction: 6.50 GJ/t

- Heating the solids to about 1050 °C: 1.45 GJ/t

- Covering the carbon losses in the ash, in the dust of the flue gas and in the sponge iron: 1.52 GJ/t

- Covering the heat loss in the flue gas: 5.55 GJ/t

- Covering the heat loss by radiation of the rotary tube kiln: 1.01 GJ/t

16.03 GJ/t

For calculating the reaction heat required for the overall reaction by means of the known enthalpies for Fe₂O₃ and CO the following equation applies:

\[ Fe₂O₃ + 3C = 2Fe + 3CO + 469.47 \text{ kJ} \]

The heat of reaction for the post-combustion of 3 moles CO with gaseous oxygen may be calculated from the following equation:

\[ 3CO + 3/2 O₂ = 3CO₂ - 846.46 \text{ kJ} \]
From this follows per 2 moles Fe an energy excess of 378.99 kJ which is available for heating the material and for covering losses. The corresponding excess per t sponge iron then amounts to 2.97 GJ/t if any iron still in oxide form is bound as FeO and if as stated above sponge iron metallised to 92% is produced from an ore of 66% Fe.

This excess amount of heat of 2.97 GJ/t of sponge iron, when bearing in mind the endothermal reduction reaction is insufficient, as shown by the above stated thermal balance, for covering the overall thermal requirements. The additional thermal energy which must therefore be made available is:

$$16.03 - (6.50 + 2.97) = 6.56 \text{ GJ/t sponge iron}$$

Since this amount of heat is to be generated by the combustion of volatile components of the coal having the above stated analysis with atmospheric oxygen and since when feeding 0.593 t of coal/t sponge iron, this combustion of the volatile components yields heat in an amount of

$$0.593 \times 9.23 = 5.47 \text{ GJ/t sponge iron}$$

it is now merely necessary to generate the small difference of 1.09 GJ/t sponge iron by the combustion of solid carbon.

On the basis of the practical experience that in the case of the readily reactive coal employed all particles smaller
...in the case of that particle range to introduce into the kiln only a further 59 kg coal/t sponge iron. If this coal is pneumatically injected from the discharge end, this corresponds to a proportion of coal fines of particle sizes smaller than 3 mm of only 10.0% of the total injected coal.

Each 3 mm will be combusted completely, it will be necessary in the case of this material to select for covering the iron then there are used as form is made of iron man.

Sponge iron, reaction, and use for feeding them. The iron forms the function of the form. The iron is made of iron man.

In the case of that particle range to introduce into the kiln only a further 59 kg coal/t sponge iron. If this coal is pneumatically injected from the discharge end, this corresponds to a proportion of coal fines of particle sizes smaller than 3 mm of only 10.0% of the total injected coal.

...in the case of that particle range to introduce into the kiln only a further 59 kg coal/t sponge iron. If this coal is pneumatically injected from the discharge end, this corresponds to a proportion of coal fines of particle sizes smaller than 3 mm of only 10.0% of the total injected coal.

...in the case of that particle range to introduce into the kiln only a further 59 kg coal/t sponge iron. If this coal is pneumatically injected from the discharge end, this corresponds to a proportion of coal fines of particle sizes smaller than 3 mm of only 10.0% of the total injected coal.
The claims defining the invention are as follows:

1. Process for the reduction of oxidic iron ores by means of solid high volatile reductants in a rotary tubular kiln in which oxygen-containing gases or oxygen are introduced at localities distributed over the length of the kiln, at least part of the reductants being so introduced from the discharge end of the kiln as to be distributed over a substantial region of the kiln charge bed, and any balance of the reductants as well as the oxidic iron ores and additives being fed at the feed end of the kiln, wherein at least 60% of the solid reductants, excluding the recycle char are introduced from the discharge end and contain not more than 20% of the fines components of particle size less than 3 mm of the total reductants.

2. Process according to claim 1, wherein 70 to 85% of the reductants are introduced from the discharge end and contain not more than 15% of the fines content of the total reductants of less than 3 mm particle size.

3. Process according to claim 1 or 2, wherein the reductants introduced from the discharge end are so injected pneumatically or mechanically that they become distributed over the lowermost 30 to 70% of the kiln length, i.e. measured from the discharge end.
the following statement is a full description of this invention including the best method of performing it known to us:

4. Process according to claim 3, wherein the reductants introduced from the discharge end are distributed over the lowermost 50 to 60% of the kiln length.

5. Process according to claim 3 or 4, wherein only 30 to 50% of the reductants introduced from the discharge end contain that amount of fines which overall is earmarked for introduction from the discharge end, these reductants being so introduced that they become distributed over at the most the lowermost 20% of the kiln length and the remainder of the reductants to be introduced from the discharge end is distributed over the remaining lower part of the kiln length extending beyond 20%, measured from the discharge end.

6. Process according to any one of the preceding claims, characterised in that the proportion of reductant fed from the feed end in terms of quantity and composition is so proportioned that the amount of heat generated by the combustion of the liberated volatile component covers the energy requirements for drying, calcining and preheating the kiln charge.

7. Process for the reduction of oxidic iron ores by means of solid high volatile reductants in a rotary tubular kiln in which oxygen-containing gas or oxygen are introduced at localities distributed over the length of the kiln, at least part of the reductants being so introduced from the discharge
end of the kiln as to be distributed over a substantial region of the kiln charge bed, and any balance of the reductants as well as the oxidic iron ores and additives being fed at the feed end of the kiln, wherein at least 60% of the solid reductants, excluding the recycle char are introduced from the discharge end in two portions, a major portion substantially free of fines smaller than 3 mm which is distributed over a kiln length region from 20% upwards measured from the discharge end and a lesser portion containing sufficient such fines for covering with their heat of combustion by immediate combustion the thermal deficiency prevailing near the discharge which end of the kiln is distributed over the lowermost 20% of the kiln length, the balance of the reductants, including the balance of fines in the reductants being introduced from the feed end as part of the kiln charge bed.

8. Process according to any one of the preceding claims, wherein the reductants introduced at the feed end are introduced jointly with the oxidic iron ores and additives.

9. Process according to any one of the preceding claims wherein oxygen-containing gases or oxygen are/is introduced by way of shell nozzles appropriately distributed and regulated over the length of the kiln.

10. Process according to claim 1 or 7, substantially as described by way of example.
11. Sponge iron produced by a process as claimed in any one of the preceding claims.

DATED THIS 17th DAY OF August 1984.

FRIED. KRUPP GESELLSCHAFT MIT BESCHRANKTER HAFTUNG

Patent Attorneys for the Applicant
F.B.RICE & CO.