Title: PRODUCTION OF CARBONACEOUS METAL ORE PELLETS

Abstract: A process for producing metal ore pellets from a particulate carbon-based material, a metal ore material, and a silicate-based binder which includes one or more surfactants, comprising the steps of: admixing the materials and binder, and agglomerating the so-formed mixture by tumbling to form the pellets at ambient temperature. The tumbling action, such as in a rotary drum, serves to agglomerate the particles and bind the mixture into the pellets. No mechanical compression force is required. The process provides a simple but efficient process for using waste carbon-based materials and waste metal ore materials, and forming a usable product, which is ready for smelting. Rotating drum or pan agglomerators are relatively low cost to build, and are capable of very high tonnage throughputs.
PRODUCTION OF CARBONACEOUS METAL ORE PELLETS

The present invention relates to a metal ore product and a process for making same.

The steel making industry is a large and important industry in the world. Steel production at an integrated steel plant involves three basic steps. Firstly, the carbon source used to melt iron ore is produced. Next the iron ore is melted in a furnace. Finally, the molten iron is processed to produce steel. Coke is a common source of the carbon used to melt and reduce iron ore. Coke production begins with pulverized, bituminous coal.

A continuing problem in many solid-based fuel production, e.g. coal mining, is dealing with waste 'fine' materials. As much as 10% of run-of-mine can end up as "fines" (generally about <3mm) or 'ultra fines' (micron or submicron). This fine coal is often unsuitable for any subsequent process and, even where the size is not a problem, retains large
amounts of water (10%-30%) which can make it
"sticky", difficult and inefficient to handle
transport and burn.

Meanwhile, another material that is currently deemed
unusable is metal ore 'fines'. As much as 10 or 20%
of ore processing and grinding can result in 'fines'
(generally about less than 2-3mm) or ultra fines
(micron or sub-micron size). Like coal fines, metal
ore fines are unsuitable for subsequent industrial
processes, and are generally deemed to be waste
material. One known process for their use involves
rolling, roasting and subsequent heating the fines
to a very high temperature in order to form ore
'marbles'. However, significant machinery is
required for this process, and it is not generally
economically viable to pursue.

It is an object of the present invention to provide
a product and process able to use such waste
materials in an economic manner.

Thus, according to one aspect of the present
invention, there is provided a process for producing
metal ore pellets from a particulate carbon-based
material, a metal ore material, and a silicate-based
binder which includes one or more surfactants,
comprising of the steps of:

admixing the materials and binder, and
agglomerating the so-formed mixture by tumbling to
form the pellets at ambient temperature,
The use of a silicate-based binder which includes one or more surfactants allows the process of the present invention to create pellets at ambient temperature. Forming metal ore pellets at ambient temperature has not been achievable by any prior art process.

The pellets are 'firm' or 'rigid' in the sense that they are handleable, and are able to be stored, stacked, and/or transported immediately, without requiring any separate active curing step or steps. That is, the pellets cure without any assistance or further treatment, especially heat and/or pressure treatment. The prior art processes required iron ore lumps to be formed by aggressive rolling, roasting and high heating with heat and/or (forced air) pressure before such lumps were rigid and handleable. Thus, the pellets of the present invention could be used and/or transported immediately after forming.

The tumbling action, such as in a rotary drum, serves to agglomerate the particles and bind the mixture into the pellets, usually with a variable size distribution. No mechanical compression force is required, (with its attendant low production rate and high cost), and the process of the present invention can be carried out at ambient temperature. By being able to carry out the process at ambient temperature, no additional equipment is required for any active second stage treatment, or to provide an
elevated temperature. This naturally eliminates the
need for a power source, e.g. fuel to be burnt, to
create the elevated temperature, which action is
usually a significant economic requirement of an
industrial process.

The binder of the present invention allows the
pellets of the present invention to be formed and to
cure in a ‘cold fusion’ process. That is, the
pellets can be formed and cure without the need for
any external heat input.

In addition, the present invention is particularly
advantageous by being able to be a ‘single stage’
process, avoiding the need for any pre-mixing or
treatment of the constituents involved, and the
requirement for any post-forming treatment. From a
capital and economic perspective, a single stage
process reduces the requirements needed to set up a
plant adapted to provide the process of the present
invention, and lowers the costs of operation by
having a single stage process which is run at
ambient temperature.

The present invention is also advantageous in using
inorganic binders, as opposed to the generally
organic materials used as binders in prior art
processes. The use of inorganic binders reduces the
complexity of the process, and again reduces the
need for any pre-treatment or mixing of binder
materials. The use of an inorganic silicate-based
binder has two further advantages. Firstly, such
binders do not impact on the burn quality of the carbonaceous material (as they do not burn), in contrast with organic materials such as starches, (which do burn, and which therefore effect the burn quality and thus heat content value of the formed material). Such binders are also clear of any environmental implications (as they do not burn), again in contrast with organic binders.

Once the pellets are formed, they can also cure to provide the final form of the pellets. In view of the present invention, such curing can occur at ambient temperature, and can also occur without any active and/or separate curing step, especially a heat treatment step as used in the prior art. The pellets will cure over time without any external influence. Thus, they could be allowed to stand, for example, for some time, such as 1-10 days, at a suitable position or location, whilst curing occurs after the tumbling. Like concrete, curing may continue for some time, for example over several days, but the invention provides pellets with sufficient solidity after tumbling, that they are ready to be stored, stacked, transported, used, etc as they cure.

The concept of curing as used herein includes any drying required of the formed pellets in addition to the chemical process occurring at at least the surface of the pellets as they are being formed, preferably to provide a hardened shell. As such, it is not intended that the present invention provides
any separate drying step or action, (being in
relation to one or more liquid materials or
substances, such as water, evaporating from the
pellets as they are formed and cured). Any such
post pellet-forming drying action is regarded as
secondary or minor compared to the act of forming
and curing the pellets.

Preferably, the process provides pellets having a
hardened outer portion, skin, casing or shell. More
preferably, the interior of the pellets is dry, and
wholly or substantially has a small, preferably
micro, aerated or porous form. That is, the action
of the surfactant to draw the silicate binder to the
surface of the pellets as they are being formed
creates air pockets and bubbles in the interior, the
benefit of which is discussed hereinafter.

In one embodiment of the present invention, water is
part of the material and binder mixture, either by
being part of the material, part of the binder,
added separately, or a combination of any of these.

The amount of water needed or desired for the
process of the present invention may depend upon the
nature of the particulate material and the binder.

For example, listed below are various types of mined
coal, and their generally found moisture content
(m/c) as the coal is mined, their heat content (h/c)
and their carbon content.
The heat content of coal can be directly linked to the moisture content. Therefore, the heat content of high grade anthracite with a moisture content of 15% will have a heat content of 26-33 mj/kg on a moist mineral-matter free basis. At the other end of the scale, lignite, the lowest rank of coal, will have a moisture content of up to 45%, with a heat content of only 10-20 mj/kg on a moist, mineral matter free basis.

It is a particular advantage that the present invention can use any type of ‘wet’ or ‘dry’ particulate carbon-based material, although any wet material preferably has a maximum water content of 10-15%. Such a moisture level can be achieved by grinding, which has a drying effect, (although the power required therefor is a lot lower than the power required for grinding coal to a powderous form ready for burning in a power station or the like).
Such material is generally still regarded in the art as being ‘wet’, especially in relation to e.g. the briquetting process, which requires its material to be absolutely dry.

In some circumstances, it is preferred to have a dry particulate material. In other circumstances, the material may be derived from a wet fuel source, such as peat and coal tailings dams, and any reduction in the amount of drying needed (compared with for example the briquetting process) reduces the overall energy input required to form the fuel product.

The process of the present invention is directly usable with moisture-rich coal fines and similar products, as any water content of the binder can be reduced in line with the level of moisture in the coal without affecting the process. Once the pellets have been formed, their hardened shell wholly or substantially stops or significantly reduces water ingress, especially if waterproofing additives are used. Once fully cured, the pellets can have a moisture content of at least half that of the particulate starting material, and possibly less than 5%, and thus be sufficiently dry for immediate and easy grinding to form a suitable fuel product for a power station.

A reduction in moisture also provides a direct increase in the heat content value of the product as it is burned, hence increasing its efficiency and economic value. This economic benefit extends to
transportation of such a product, in comparison with
cost of transporting 'wet' or moisture-rich
material. Indeed, the present invention provides a
process whereby with consideration of the type and
amount of binder(s) used, and the process
parameters, a fuel material can be provided which
has a desired or pre-determined burn value or the
like, which, in particular, could suit the local
economic conditions for the fuel source. Different
locations and countries mine different types and
grades of coal, and they therefore use such coals in
different ways in order to try and maximise their
economic value. The present invention provides a
particular advantageous process to benefit what is
currently regarded as a waste material from current
industrial processes.

Thus, the present invention also provides
significant moisture reduction in a fuel product,
converting an inefficient fuel product into an
efficient fuel product.

In a preferred embodiment of the present invention,
the amount of water for the process is adjusted in
the binder component prior to its admixing with the
other materials. The calculation of this binder to
water adjustment is dependent on the moisture
content of the particulate material.

According to another embodiment of the present
invention, the particulate carbon-based material is
generally of a maximum size or grade of 3mm or
lower. Coal 'dust' or 'fines' can often be of a
sub-micron size.

More preferably, the particulate material has a
range of sizes or grades; preferably biased towards
fine or finer particle sizes.

Carbon-based particulate material suitable for the
present invention can be accepted wet or dry, and
could be provided by any type of maceral fuel,
including peat and lignite through to sub-bituminous
coals, anthracite fines, petroleum coke fines and
the like, as well as sewerage wastes, biomass,
animal wastes and other hydrocarbon materials that
could be considered a fuel source. The particulate
material may also be a combination of two or more
starting materials or 'ingredients', not necessarily
premixed, and such as those hereinbefore mentioned,
so as to provide 'hybrid' pellets.

Suitable materials also include low grade or
processed fuels, as well as hitherto 'waste'
products, whose clean combustion would help lower
overall pollution levels.

The present invention is not affected by high ash
content or sulphur content in the particulate
material.

Any suitable silicate-based binder can be used for
the present invention, which binder may be a
homogeneous or heterogeneous material, such as
cements and raw silicates like calcium, sodium or potassium.

The process may include the addition of one or more further ingredients into the mix, either separately or integrally with the binder. Such further ingredients include lime, inorganic binders, cements, and waterproofing additives. A cementitious material can assist in the green-strength of the pellets, and possibly in forming the hardened outer surface or shell for the pellets as described hereinafter.

Lime or cement helps to inhibit sulphur emission upon burning of the so-formed pellets. It is a particular advantage of the present invention that the use of lime or other types of calcium hydroxide (which are known to be sulphur-absorbing agents) are admixed with the particulate carbon-based material. The increased mixing of such sulphur-absorbing agents with sulphur-containing carbon-based materials reduces the need for any sulphur-absorbing apparatus such as scrubbers and the like at the end of a fuel-burning process. Indeed, it is considered that the present invention can achieve a reduction of sulphur emission (usually in the form of sulphur dioxide) by 70-90%, or possibly more.

There are many metal ores which are mined and extracted for use in industrial processes. All such ores are useable with the present invention as metal ore material, either individually or in any
combination of metal ores, optionally with the same
or different metals, and collectively referred to
herein as 'metal ore material'. One well known ore
is iron ore, which is a starting material in the
production of steel.

Iron can be extracted from its ores by a
carbothermic reaction (i.e. reduction with carbon)
in a blast furnace at temperatures of about 2000°C.
In a blast furnace, iron ore, carbon, possibly in
the form of coke as mentioned above, and a flux such
as limestone, are fed into the furnace, while a
blast of heated air is forced into the furnace at
the bottom. In the furnace, the coke, acting as the
source of carbon, reacts with oxygen in the air
blast to produce carbon monoxide, which reduces the
iron ore. The flux is present to melt impurities in
the ore.

The present invention provides the ability for the
source of carbon required for ore extraction to be
already combined with the iron ore, as well as using
two materials previously considered to be 'waste'.
The pellets of the present invention are in a
suitable size and shape for direct introduction into
a furnace, and for the subsequent heating step, and
smelting. In this way, the particulate carbon-based
material provides at least one source of carbon for
metal reduction, and a carbon fuel.

A similar action can be carried out for processes
involving other metals such as copper or nickel, to
be extracted from their ores where a carbon-based material is required to reduce the metal to its elemental form, or where any other reaction with a carbon-based material is desired. The present invention also allows the particulate carbon-based material to be 'fuel' to heat the ore for a process other than metal extraction.

The addition of a sulphur-absorbing agent into the pellet-forming process, along with any grinding of the pellets for subsequent use, provides two particular advantages. Firstly, the ability of the process of the present invention to provide wholly or substantially 'dry' pellets reduces the energy input required to effect the grinding of the pellets prior to their burning, as described above, and secondly, grinding of the pellets increases the mixing of the sulphur-absorbing agent(s) with the carbon-based material, thus increasing the efficiency of the sulphur-absorption, and so reducing the sulphur-emission.

Thus, the process of the present invention can further include the step of grinding, crushing or otherwise particularising the pellets, preferably in a form ready to use in a carbon-burning situation.

The particulate carbon-based material, metal ore material, and binder, and any other separate reagents or ingredients to be added, can be admixed using any known process or arrangement, including simple mixing. Because the next part of the process
is a tumbling action, absolute homogeneous mixing of
the reagents or ingredients prior to the tumbling
is not essential, as the tumbling action will
generally further the mixing action if necessary or
desired. In some circumstances, the admixing may at
least partly occur during the tumbling action, such
that the actions of the invention may not be wholly
distinct.

In one embodiment of the present invention, the
binder is coated on to the materials. One method of
coating is to spray the binder on to the materials.

In another embodiment of the present invention, the
materials are moving prior to and/or during mixing
with the binder, and/or the materials are in a
dispersed arrangement. One particular suitable form
of this is a falling curtain of the materials, such
as at conveyor transfers, inside pelletising drums
or pans, and from stockpile load outs, etc.

In another embodiment of the present invention, the
particulate material, metal ore material and binder
are directly and/or immediately undergo tumbling
after their contact with each other.

The tumbling action serves to agglomerate the
materials and binder mixture to form particles of
greater and greater size, generally having a
spherical or ovoid shape. The size of the so-formed
pellets can be adjusted based on the process
conditions for tumbling, such as rotation speed,
moisture content, impact force and residence time. The pellets could also be screened and/or recycled during or after pelletising to produce a desired, e.g. narrower, size distribution.

One suitable apparatus for providing tumbling action is a rotary drum. Rotary drums are well known in the art. Their output can be dependent upon the length, diameter, speed of rotation and angle of mounting of the drum, and the output can vary from single figure tonnes per hour, to hundreds of tonnes per hour per drum.

The general sizes and dimensions of agglomerator drums, such as pan, rotary and conical drums, are known in the art, as are their process variations to provide variation in the products formed. See for example UK Patent No 787993.

Rotary drums have low capital and low operating costs, especially in comparison with briquetting and other solid-forming machinery or plants. They can even be provided in mobile form, such that the process of the present invention can be provided where desired or necessary, e.g. moved and located to where one or both of the materials are currently stored or ‘dumped’, rather than requiring significant movement (and therefore cost) for transporting a or the materials to a fixed processing site.
The agglomerate action may be carried out in one or more stages, which stages could be connected, such as the tumbling conditions changing in the same drum, or the materials being fed directly into another agglomerator. Or, such actions could be separate. In one arrangement for multi-stage agglomeration, the tumbling conditions are variable or varied for each stage. The conditions may be altered either in a continuous manner or action, or discretely.

Where the process of the present invention involves tumbling the mixture in a rotary drum, one or more rotary drums may be used for the agglomeration, preferably in series.

The surfactant(s) serve to draw the silicate-based binder towards the surface of the forming pellets, such that as they are created and start to cure, the pellets will form and then continue to have a harder outer portion, skin, shell or surface, compared to their interior. Thus the pellets have a variable density towards the core; the density being greater at the surface. Indeed, the ‘shell’ layer or portion will generally have a high density in comparison with the lower density of the ‘interior’.

More preferably, the pellets have sufficient hardness once formed to allow handling, stacking and/or transportation without any significant breakage.
The curing of the pellets may start during or be part of the agglomeration action.

The method of the present invention may include one or more sizing steps. That is, to grade the size of the so-formed pellets to that desired or necessary. This could include extracting those pellets which are damaged or undersized, which pellet material could be recycled back into the process of the present invention. When coal is mined, cleaned and transported, considerable quantities of fine coal (particles less than 5mm) are generated. Similarly with metal ore mining. The present invention can form this fine coal and fine metal ore(s) into approximately 50mm pellets with very low moisture, without any change to the chemical properties of the coal or ore(s). The pellets can used then be handled, transported and used as normal ‘lump’ coal and metal ore(s).

Following any initial curing, the formed pellets could be rested for some time, possibly a number of days such as 3-7 days, to provide or allow for curing to finish. Like other curing products, the pellets continue to cure to gain strength over time, such as a further number of days or weeks.

According to another aspect of the present invention, there is provided a pellet product formable at ambient temperature by agglomeration of a particulate carbon-based material, a metal ore
material, and a silicate-based binder including one
or more surfactants.

According to another aspect of the present
invention, there is provided a product whenever
formed by a process as herein described.

The pellet product of the present invention is a
material which is easily storable. It is also
easily transportable due to its variable diameter
distribution. This enhances stacking concentration,
which also reduces abrasion and consequential
breakage of the pellets.

The product is formed from currently 'waste'
materials, thereby increasing the efficiency of
current metal ore and solid-fuel extraction and
production.

The product preferably allows a very high percentage
of combustion (possibly 100% combustion), so as to
leave little or no combustible fuel in the ash.

**Example**

The coal fines and iron ore fines are carried along
and any dry reagents are added thereto. They then
fall from the end of a conveyor belt. The liquid
binder is sprayed onto the falling curtain of fines,
which together fall into a rotating drum, generally
1-5m (such as 3m) in diameter. As the mixture
tumbles while being sprayed with the binder and
water mixture, it forms small pellets which
agglomerate and grow, forming pellets of desired
shape and size.

The drum can be lined with loosely fitting heavy
duty rubber sheet to avoid material sticking to the
sides of the drum. The drum is set at an incline
(e.g. 1-3%) to aid progression of the pellets
therealong, and to control the residence time in the
drum. The completed pellets exit at the opposite
end of the drum onto another conveyor.

Pellets can be varied in size with only operational
drum adjustments (speed of rotation, moisture
content and longitudinal drum angle which directly
affects residence time in the drum). Expensive
mould changes, such as in present briquetting
operations, are not required to vary the product
dimensions.

Some forming and even some curing may take place in
another rotating drum, similar to but having a
larger diameter than the agglomerating drum. It may
also be of greater diameter and longer than the
agglomeration drum. Here the pellets progress
slowly through the drum, allowing sufficient time
for the pellets to initially cure or receive surface
treatment, and thereby allow immediate handling and
stacking. The residence time within this drum is
dependent on the coal and iron ore characteristics,
and its use can be determined in pre-production
tests.
Should the green strength of the pellets be poor, certain additional binders or cementitious chemicals can be added to rapidly speed-up the curing process, and thereby give quicker and stronger initial green strength to aid handling, or handleability, etc. Broken and undersized pellets can be removed using for instance a slotted section of drum or a vibrating screen at the drum exit. The damaged and undersized pellets can then be returned to the agglomerating drum for reprocessing.

At this stage the pellets can be further graded to the desired cross section if necessary. Any damaged and undersized pellets can then be returned to the agglomerating drum for reprocessing.

The pellet sizing could even be designed to be made dependent upon proposed use. The pellet size can be adjusted by means of changes to process conditions, equipment configuration, and even reagent dosage.

The pellets can then be stockpiled for curing. During this time, generally between 3-7 days for coal fine pellets, and depending on ambient temperature, the pellets reach such strength as to allow full handling. No heating or force draught drying is required.

The spherical shape of the pellets will allow air to move freely through the stockpile to assist the curing process and prevent heat build up and the
risk of spontaneous combustion. At this stage, the pellet surface is also tightly sealed, preventing air ingress into the pellets, and so also slowing the effect or chance of any spontaneous combustion. If spontaneous combustion is still a problem, preventative reagents can be added during agglomeration.

A further advantage of the present invention is the very complete combustion of the contained fuel in the pellets due to the high gas transfer rates and the maintenance of the integral structure of the pellets until combustion is complete. The retaining hardened shell, skin, etc, allows for significant heat increase or build-up inside the pellet, causing very high levels of combustion, resulting in the completion of any pre-designed chemical reactions in the interior content of the pellet. As the content is dry and porous form, generally of a ‘fine’ nature still, and is now pre-heated, rapid and so complete combustion of the content occurs. The pellets maintain their form even at white heat, and show very stable combustion characteristics.

In particular, the process of the present invention can involve no forced drying of the pellets because the action of any surfactant(s) used is maximised in ambient temperatures. Moreover, where water is used, the surfactant causes the binder-containing moisture to rapidly migrate to the surface of the pellet by capillary action, giving the ‘egg shell’ effect of a hardened surface and softer interior,
due to the final heavy surface concentration of the binder. This results in a significantly enhanced skin strength, giving a very robust and low moisture content pellet (approximately 5%), which also resists moisture absorption from the air.

One further application of the present process is lowering the feed moisture of pulverised coal fuels in ore processing, where the coal fines or coal tailings are pelletised and allowed to thoroughly cure and dry before being pulverised and burnt in a furnace. The general moisture content found in current coal fines dumps is usually in the range 12-35%, making them very difficult to use or blend with other feeds.

As can be recognised from the above, the process of the present invention, overcomes or solves a number of financial and operational problems.

Once the 'egg shell' effect has been fully developed after curing, the pellet will retain its strength even during white heat combustion. This allows high temperature reactions to take place inside the pellet resulting in much higher levels of combustion of the fuel, giving effective oxidation and sequestration of any contained sulphur, and negligible unburnt carbon levels in the residue ash. The shell effect allows the pellet to retain its structure during combustion, resulting in less particulate emissions in the flue gas.
The present invention provides significant benefits compared with present technologies, including:

- <3mm coal/lignite fines can be pelletised dry or direct from a filtration plant.
- Tonnage throughput can be from 10 tones per hour (community size) up to 100 tonnes per hour per pelletising line.
- High level of automation can be used during pelletising for accurate control and reagent usage.
- Pellets just air dry while chemically ‘curing’.
- Pellets can be handled by bulk handling equipment when cured or alternatively bagged when ‘green’.
- Pellet size can be customised from 5mm to 150mm if required depending upon coal characteristics and process parameters.
- Special heavy duty reagents can be added for high strength, for rapid cure, for high temperature strength, and for enhanced water resistance.
- Pyrite removal can be reduced or eliminated due to various binder combinations to eliminate SO₂ due to gas transfer to form CaSO₄ inside the pellet.
- Due to excellent combustion characteristics, high ash coal fines will ignite and burn with high efficiency.
- Long lasting combustion, with high percentage carbon combustion.
- <20mm coal can be crushed and pelletised with fines for high value pellets.
• Contaminated coal or waste products such as
  sawdust, rice husks, sewage, animal wastes,
  petroleum coke or waste oil can be included into
  the pellets.
• Residual ash has negligible un-burnt fuel (e.g.
  coal) residue and is excellent for other
  industrial uses.
• Residual ash can also be pelletised with similar
  binder reagents for concrete feedstock, aggregate
  blending and high porosity landfill.
• Lignite and peat can be treated with identical
  technology or can be blended with other fuel
  sources to create hybrid pellet fuels with pre-
  designed characteristics such as smokeless
  burning.

The present invention is usable with all types of
coal fines, which will have a varying amount of
moisture and sulphur content. Generally, pellets
ranging from 5-50 mm diameter are formed.

The present invention provides a simple but
efficient process for using waste carbon-based
materials and waste metal ore materials, and for
forming such materials into a form which is easily
and efficiently combustible. Rotating drum or pan
agglomerators are relatively low cost to build, and
are capable of very high tonnage throughputs.
Claims

1. A process for producing metal ore pellets from a particulate carbon-based material, a metal ore material, and a silicate-based binder which includes one or more surfactants, comprising the steps of:

   admixing the materials and binder, and

   agglomerating the so-formed mixture by tumbling to form the pellets at ambient temperature.

2. A process as claimed in claim 1 carried out as a single stage process.

3. A process as claimed in Claim 1 or Claim 2 wherein the process is carried out without requiring a separate active curing step or steps.

4. A process as claimed in any one of the Claims 1 to 3 wherein the pellets cure after tumbling at ambient temperature.

5. A process as claimed in any one of the preceding claims wherein the pellets form a hardened shell.

6. A process as claimed in any one of the preceding claims adapted to provide pellets of a variable size distribution.
7. A process as claimed in any one of the preceding claims wherein the particulate material and/or binder includes water.

8. A process as claimed in Claim 7 wherein the binder includes water prior to admixture with the particulate and metal ore materials.

9. A process as claimed in any one of the preceding claims wherein the particulate carbon-based material and metal ore material are generally of a maximum size or grade of about 3mm or lower.

10. A process as claimed in any one of the preceding claims wherein the particulate carbon-based material is coal dust or coal fines.

11. A process as claimed in any one of the preceding claims wherein the metal ore material is iron ore.

12. A process as claimed in Claim 11 wherein the iron ore is iron ore fines and/or ultrafines of a size less than 2mm.

13. A process as claimed in any one of the preceding claims wherein the particulate carbon-based material is a combination of two or more carbon materials.
14. A process as claimed in any one of the preceding claims wherein the binder is partly, wholly or substantially sodium silicate or potassium silicate.

15. A process as claimed in any one of the preceding claims wherein the process includes the addition of one or more further ingredients.

16. A process as claimed in Claim 15 wherein the or each further ingredient is selected from the group comprising: lime, inorganic binders, cements and waterproofing additives.

17. A process as claimed in any one of the preceding claims wherein the particulate carbon-based material, metal ore material and binder are at least partly mixed with agitation.

18. A process as claimed in any one of the preceding claims wherein the binder is sprayed on to the particulate carbon-based material and/or the metal ore material.

19. A process as claimed in any one of the preceding claims wherein the pellets have a spherical or ovoid shape.
20. A process as claimed in any one of the preceding claims wherein the pellets are screened after tumbling.

21. A process as claimed in any one of the preceding claims wherein the tumbling is carried out in a rotary drum.

22. A process as claimed in any one of the preceding claims wherein the process does not require any pre-treatment of the particulate carbon-based material and/or the metal ore material.

23. A process as claimed in any one of the preceding claims for reducing moisture in the carbon-based material, preferably to less than 5%, compared with the weight of the moisture in particulate carbon-based starting material.

24. A process as claimed in any one of the preceding claims wherein the mixing of the particulate material, metal ore material and binder occurs by the tumbling.

25. A pellet product formable at ambient temperature by agglomeration of a particulate carbon-based material, a metal ore material, and a silicate-based binder including one or more surfactants.
26. A pellet product whenever formed or obtainable by a process as claimed in any one of Claim 1 to 25.

27. A pellet product as claimed in claim 25 or claim 26 ready for smelting.

28. A pellet as claimed in any one of Claims 25 to 27 wherein the pellet product includes one or more sulphur-absorbing agents.

29. A pellet as claimed in any one of Claims 25 to 28 wherein the metal ore material is iron ore fines and/or ultrafines.

30. A pellet as claimed in any one of Claims 25 to 29 having a hardened shell.

31. A pellet as claims in any one or Claims 25 to 30 having a variable density towards its core.

32. A pellet as claimed in any one of Claims 25 to 31 having a dry interior.

33. A pellet as claimed in any one of Claims 25 to 32 having sufficient rigidity after tumbling to allow handling, stacking and/or transportation without any significant breakage.
34. A pellet as claimed in any one of Claims 25 to 33 wherein the particulate carbon-based material is coal dust and/or coal fines.
**INTERNATIONAL SEARCH REPORT**

**International application No**

PCT/IB2006/000078

---

**A. CLASSIFICATION OF SUBJECT MATTER**

INV. C22B1/24 C22B1/243 C22B1/245 C22B7/02

---

**B. FIELDS SEARCHED**

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

---

**Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched**

Electronic data base consulted during the international search (name of data base and, where pertinent, search terms used)

EPO-Internal, PAJ, WPI Data, COMPENDEX

---

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>US 3 153 586 A (WIENERT FRITZ 0 ET AL) 20 October 1964 (1964-10-20)</td>
<td>1-9,14, 15,19, 22-28, 30-33, 10-13, 16-18, 20,21, 29,34</td>
</tr>
<tr>
<td>Y</td>
<td>examples I-V</td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td>US 3 400 179 A (WIENERT FRITZ 0) 3 September 1968 (1968-09-03) example 2</td>
<td>10,13,34</td>
</tr>
<tr>
<td>Y</td>
<td>GB 787 993 A (FAWKHAM DEVELOPMENTS LIMITED) 18 December 1957 (1957-12-18) cited in the application page 1, line 12 - line 34; figure 1</td>
<td>17,20,21</td>
</tr>
</tbody>
</table>

---

**Further documents are listed in the continuation of Box C.**

---

**See patent family annex.**

---

**Date of the actual completion of the international search**

5 September 2006

---

**Date of mailing of the international search report**

21/09/2006

---

Name and mailing address of the ISA

European Patent Office, P.B. 5816 Patenten 2 NL - 2280 HJ Rijswijk
Tel. (+31-70) 340-2000, Tx. 31 051 epo nl, Fax: (+31-70) 340-3016

Authorized officer

Bombeke, M

---

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>US 4 273 575 A (LITZINGER ET AL) 16 June 1981 (1981-06-16) column 2, line 32 - line 59; example 1</td>
<td>11,12, 16,18,29</td>
</tr>
<tr>
<td>Y</td>
<td>EP 0 508 166 A (ZIA METALLURGICAL PROCESSES, INC) 14 October 1992 (1992-10-14) column 3, line 22 - line 56; figures 1,2</td>
<td>1-34</td>
</tr>
<tr>
<td>Y</td>
<td>WO 00/75384 A (NU-ROCK INTERNATIONAL LIMITED; BEYER, ALDRIN, BERNARD; JORDAN, PIERRE;) 14 December 2000 (2000-12-14) page 4, line 24 - page 5, line 5; claims 1,2,7-10</td>
<td>1-34</td>
</tr>
<tr>
<td>Y</td>
<td>US 3 536 475 A (JEAN TRUB) 27 October 1970 (1970-10-27) claims 1-5; figure 1</td>
<td>1-34</td>
</tr>
<tr>
<td>Y</td>
<td>US 4 169 711 A (ANDERSON, TIMOTHY J) 2 October 1979 (1979-10-02) claims 1-6</td>
<td>1-34</td>
</tr>
<tr>
<td>Patent document cited in search report</td>
<td>Publication date</td>
<td>Patent family member(s)</td>
</tr>
<tr>
<td>---------------------------------------</td>
<td>-----------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>US 3153586</td>
<td>20-10-1964</td>
<td>GB 916680 A</td>
</tr>
<tr>
<td>US 3400179</td>
<td>03-09-1968</td>
<td>DE 1283200 B</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GB 1102153 A</td>
</tr>
<tr>
<td>GB 787993</td>
<td>18-12-1957</td>
<td>NONE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EP 0004637 A1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>JP 54142115 A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AU 658174 B2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AU 1388692 A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BR 9201258 A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CA 2061548 A1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DE 69233172 D1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DE 69233172 T2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ES 2206441 T3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>JP 5125454 A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>KR 234844 B1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MX 9201682 A1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>US 5186741 A</td>
</tr>
<tr>
<td>ZA 200105780</td>
<td>24-06-2002</td>
<td>NONE</td>
</tr>
<tr>
<td>WO 0075384</td>
<td>14-12-2000</td>
<td>AU 5643600 A</td>
</tr>
<tr>
<td>US 3536475</td>
<td>27-10-1970</td>
<td>NONE</td>
</tr>
<tr>
<td>US 4169711</td>
<td>02-10-1979</td>
<td>NONE</td>
</tr>
</tbody>
</table>