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(54) Title: BINDER COMPOSITION AND A SINTERING PROCESS

(57) Abstract: The present invention relates to a binder composition for agglomerat- ing fine ore particles, comprising a water soluble metal salt, and a synthetic polymer, a surfactant, or a combination or mixture thereof, in a form of a solution. The present invention further relates to a process for preparing ore agglomerates comprising adding the binder composition fine ore particles to form a mixture; and forming the mixture into agglomerates. The present invention additionally relates to a sintering process comprising adding the binder composition to fine ore particles to form a mixture; forming the mixture into agglomerates; and heating the agglomerates to obtain sinter. Additionally, the present invention relates to a use of the binder composition as an additive in agglomerating ores.



## BINDER COMPOSITION AND A SINTERING PROCESS

### Field of the invention

5 The present invention relates to a binder composition for agglomeration fine ore particles and to a method for preparing ore agglomerates. The present invention further relates to a sintering process and use of the binder composition in agglomerating ores.

### Background

10 Granulating and pelletization are standard methods of agglomerating used to turn fine minerals fractions, such as iron ore, into an adequate product to be fed to the blast furnace and to the direct reduction reactors.

15 Iron ore is commonly used in the production of steel. In the first step of the steel-making process, iron is recovered from the ore by smelting in a blast furnace. To be fed directly into the furnace, the iron ore must be in the form of agglomerates of substantial size. If the ore is in the form of particles that are too small for direct feed, it is necessary to convert the iron ore particles to a sinter or to pellets.

20 Considering iron ore concentrate, the feed to a blast furnace should form a permeable bed of material, permitting gas flow through it uniformly at a high rate. Powdered iron ore concentrates containing fine particles are not suitable as feed because fines tend to pack into a non-permeable bed. In addition, the fine particles are likely to be carried away as dust by the high gas flow rates into the blast furnace and into the direction of the reduction reactor. The powdered ore must therefore be agglomerated into larger particles that will improve permeability of the furnace feed, increase the rate of reduction, and reduce the amount of material blown out of the furnace as dust.

For the fine particles, pelletization is a common method of feedstock production for the furnaces.

30 Pelletizing is an agglomeration technique in which the powdered ore is first formed into a "green" (wet) pellet or ball, which is then dried in a first separate

step and hardened in a second separate step, both usually by heating. Green pellets are made by combining moist ore with a binder and rolling it into balls using either a pelletizing disc or a pelletizing drum. The pellets are then dried, preheated, and finally fired to more than 1000 °C to harden them by sintering.

- 5 This temperature is lower than the melting point of iron oxides, and the pellets harden by recrystallization of hydrated fines ore. The fines ores are dispersed by the binder system, between the particle grain boundaries.

Common binders used to agglomerate particular iron ore include certain polymers and bentonite, although many binders have been proposed in the literature, for example various clays, ferrous sulphate, lignin sulphate, asphalt, starches, calcium and sodium compounds.

The clay minerals are among the most frequently used binders in iron ore pelletization. The main advantage of clay minerals is their good wettability, their great adhesive and cohesive force, which provides sufficient mechanical stability of the finished pellets, as well as their thermal stability. The main disadvantage of clays and other binders based on silicate minerals is that they increase silica content in the finished pellet. This has prompted continuing interest in developing binders that contain less or no silica.

Organic binders have the advantages that they are highly effective, can be specifically designed for binding particular types of particles, have highly reproducible characteristics, and do not increase the silica content. Investigations show that the improvement in natural adhesion between the powder particles caused by the organic binders is attributed to its increasing effect on the wettability on the surface of concentrates, besides an increase in the dispersion of ore fines. The increase of the dispersion degree of fines when organic binders are used entails an increase in the pellet strength by filling the empty spaces between the solid particles which form the pellets with a better finishing without dust from fines on the particles' and pellets' surface. Organic binders also burn out during sintering thus causing an increase in the micro porosity of the finished pellets.

For example, WO 2013/010629 discloses a binder composition for pelletization of fine mineral particles comprising a) at least one colloid agent, such as calcium compounds, magnesium compounds and clay materials, which exerts a cohesive force on the mineral particles forming the pellets, and b) at least

one synthetic polymer, such as urea-formaldehyde resin, vinyl acetate polymer and styrene-acrylic copolymer, which disperses mineral particles in the pellets.

US 2014/0033872 relates to binder compositions for agglomerating iron ore fines comprising: (a) about 30 to about 80% by weight one or more types of  
5 anionic or nonionic acrylamide-containing polymer, such as polyacrylamide; (b) about 10 to about 35% by weight one or more types of inorganic or organic monomeric electrolyte, such as sodium carbonate and sodium hydroxide and the corresponding calcium or magnesium salts of the preceding salts; and (c) about 10 to about 35% one or more types of finely ground wood fiber.

10 EP 1540023 B1 discloses a process for producing iron oxide-containing pellets wherein fine iron oxide particles are agglomerated in the presence of an organic binder and a binder additive which serves to improve the preheat strength of the pellets. The binder additive can be a boron-containing compound or calcium fluoride.

15 Even though there are a wide variety of methods and binder compositions for agglomerating of fine ore materials, there is still need for new and more efficient binder compositions with improved properties.

### **Summary of invention**

20 An object of the present invention is to provide a binder composition for agglomeration fine ore particles.

A further object of the present invention is to provide a method for preparing ore agglomerates.

25 Yet, a further object of the present invention is to provide a use of the binder composition in preparation of ore agglomerates.

Yet, a further object of the present invention is to provide a binder composition that binds the ore fines efficiently improving the degree of granulation.

30 Yet, another object of the present invention is to provide a binder composition that improves bed permeability to a degree where the bed level during sintering can be increased.

Yet, a further object of the present invention is to provide a sintering process which improves productivity.

Yet, a further object of the present invention is to provide a sintering process which saves energy and lowers coke consumption.

- 5 It has now been surprisingly found that in one aspect of the invention a binder composition comprising: a water soluble metal salt, such as magnesium (Mg) or copper (Cu) salt; and a synthetic polymer, a surfactant, or a combination or mixture thereof in form of a solution, preferably a dispersant or a surfactant having low molecular weight, binds ore, such as iron ore, fines very efficiently  
10 improving degree of granulation. This leads to several benefits in the production process, the most important benefit being increased productivity (tons/hour of sinter).

- The binder compositions of the present invention improve bed permeability to a degree where the bed level during sintering can be increased, which  
15 improves productivity significantly.

Dust formation in the sintering process is a problem. The developed binder compositions contain inorganic materials that remain between the ore particles when the polymer is combusted. The inorganic materials contribute to slag formation giving the sinter improved mechanical strength after sintering.

- 20 Granulation at production plants usually require significant amount of water, which needs to be evaporated in the process consuming large quantities of energy. Because of the efficient binding properties of the binder compositions of the present invention, amount of added water in the sintering process can be reduced which will lead to energy savings/lower coke consumption.

- 25 The binder composition of the present invention is preferably applied in a soluble form, preferably in a form of aqueous solution. This allows better mixing and distribution of the composition with the ore fines and thus improved performance in granulation and strength. The binder composition can be dosed as a solution, preferably as an aqueous solution, to the process  
30 enabling good homogenization of the product.

The present invention provides a binder composition for agglomeration fine ore particles as depicted by claim 1.

The present invention further provides an ore composition as depicted by claim 26.

The present invention further provides a method for preparing ore agglomerates as depicted by claim 28.

- 5 The present invention further provides a sintering process as depicted by claim 32.

The present invention further provides a use of the binder composition in granulating ore as depicted by claim 36.

## 10 Detailed description

According to the first aspect of the present invention there is provided a binder composition for agglomerating fine ore particles. More particularly there is provided a binder composition for agglomerating fine ore particles, comprising: a water soluble metal salt; and a synthetic polymer, a surfactant, or a combination or mixture thereof; in a form of a solution.

As used herein, the phrase "ore fines" or "fine ore particles" refers to ore materials that are in particulate form, e.g. in powder, dust, chip or other particulate form. In exemplary embodiments, the ore fines are particles of ore that are substantially of small particle size, for example less than about 250  $\mu\text{m}$ .

20 Ores are rocks and minerals from which metallic ore, such as iron ore, or non-metallic ore can be economically extracted. For example, iron ores are usually rich in iron oxides and vary in color from dark grey, bright yellow, deep purple, to rusty red. The iron itself is usually found in the form of magnetite ( $\text{Fe}_3\text{O}_4$ ), hematite ( $\text{Fe}_2\text{O}_3$ ), goethite ( $\text{FeO}(\text{OH})$ ), limonite ( $\text{FeO}(\text{OH}) \cdot n(\text{H}_2\text{O})$ ) or siderite

25 ( $\text{FeCO}_3$ ). Taconite is an iron-bearing sedimentary rock in which the iron minerals are interlayered with quartz, chert, or carbonate. Itabirite, also known as banded-quartz hematite and hematite schist, is an iron and quartz formation in which the iron is present as thin layers of hematite, magnetite, or martite. Any of these types of iron are suitable for use in forming the agglomerate as

30 described herein. In exemplary embodiments, the iron ore fines are substantially magnetite, hematite, taconite or itabirite. In exemplary embodiments, the iron ore fines can be contaminated with clay.

As used herein, the term “binder” or “binder composition” refers to a composition or a system of components that is added to the ore fines in order to draw them together in such a way that the mixture maintains a uniform consistency. The binder composition may be added to the ore fines as a mixture of the components or the components of the binder composition may be added separately to the ore and in any order deemed suitable by one of skill in the art.

As used herein, the term “agglomerate” refers to a small particle created by agglomerating the mixture comprising fine ore particles and the binder composition and optionally a liquid, such as water. Such mixtures may also be compressed into shapes such as pellets, briquettes or other appropriate shapes. As will be understood by those of skill in the art, the shape of the agglomerated particle is not particularly limited. In exemplary embodiments, the final particle size of the agglomerated particle is from about 1 mm to about 25 mm, in another exemplary embodiment from 1 mm to 8 mm.

The synthetic polymer is in a form of a solution in the binder composition. In one embodiment the synthetic polymer is a water soluble polymer, preferably the water soluble polymer is in a form of an aqueous solution in the binder composition.

In one embodiment the binder composition comprises a water soluble metal salt and a water soluble polymer in a form of an aqueous solution.

In another embodiment the binder composition comprises a water soluble metal salt and a surfactant in the form of an aqueous solution.

In preferred embodiment the binder composition is in a form of an aqueous solution.

Average molecular weight, in one embodiment, of the synthetic polymer is from 500 g/mol to 200000 g/mol, preferably from 500 g/mol to 10000 g/mol, more preferably from 2000 g/mol to 10000 g/mol. Here the value “average molecular weight” is used to describe the magnitude of the polymer chain length. Molecular weight distribution:  $M_w$ ,  $M_n$  and PD were measured using an Agilent 1100 series SEC apparatus equipped with a RI detector. Polymers were dissolved in THF before injection. The standards used for the determination of the molecu-

lar weight were a series of PEO (polyethylene glycol) with molecular mass ( $M_w$ ) varying from 430 to 1015000.

In one embodiment viscosity of the synthetic polymer is from 100 cP to 2000 cP, preferably from 100 cP to 1000 cP, more preferably from 200 cP to 800 cP.

- 5 The viscosity (cP) was determined using a Brookfield Digital Viscometer (model DV-I +) following the standard instructions (manual M/92-021-P405), measured at room temperature.

In one embodiment the synthetic polymer is produced by solution polymerization process.

- 10 The synthetic polymer may be a homo- or copolymer of acrylic acid, maleic acid, sulfonic acid or theirs salt, or a mixture thereof. The salt may be sodium salt, ammonium salt, methyl salt, or a mixture thereof.

In one embodiment the synthetic polymer is anionic or non-ionic synthetic polymer. Preferably the synthetic polymer is anionic synthetic polymer.

- 15 Charge density of the anionic polymer is preferably from -3 meq/g to -12 meq/g, more preferably from -7 meq/g to -11 meq/g. The charge density is determined at pH 7, and measured by titration with a Müttek™ particle charge detector (PCD-03) from BTG Müttek GmbH. The standard used was the anionic solution PES-Na (polyethene sodium sulfonate;  $c = 0.001$  mol/L).

- 20 In one embodiment the synthetic polymer is a dispersant.

In one embodiment, the dispersant is selected from a group consisting of polyacrylate, polycarboxylate (not esters), polyacrylic acid, polyacrylamide (SPAM), or mixtures thereof. Preferably the dispersant is sodium polyacrylate, poly(2-acrylamido-2-methyl-1-propanesulfonic acid) (polyAMPS), or mixtures

- 25 thereof.

In one embodiment, the surfactant is an anionic surfactant having carboxylate, sulfate, sulfonate, or phosphate group(s). Preferred anionic surfactants are alkyl ether carboxylate, alkyl sulfate, alkyl ether sulfate, alkylbenzene sulfonate, dialkyl sulfosuccinate, alkyl phosphate, or a mixture thereof, prefer-

- 30 ably sodium dioctyl sulfosuccinate.

In another embodiment, the surfactant is a non-ionic surfactant having polyether groups(s) such as polyether consisting of oxyethylene unit(s); polyhydroxyl group(s); or fatty acid alcohol, or a mixture thereof. Preferred non-ionic surfactants are ethoxylated linear alcohol, ethoxylated alkyl phenol, fatty acid ester, fatty acid alcohol, amine and amide derivatives, alkylpolyglucosides, etheleneoxide/propyleneoxide copolymer, polyalcohol, ethoxylated polyalcohol, thiol (mercaptan) and derivatives thereof, fatty acid ethoxylate, or a mixture thereof, preferably tridekanoethoxylate.

In one embodiment the water soluble metal salt is water soluble metal(II) salt. By metal(II) is meant bivalent metal ion; in other words a metal ion having a valence of two ( $Me^{2+}$ ).

In one embodiment the water soluble metal(II) salt is magnesium salt, copper salt, or a mixture thereof. Preferred water soluble metal(II) salt is magnesium salt. An example of suitable magnesium salt is magnesium nitrate ( $Mg(NO_3)_2$ ), such as magnesium nitrate hexahydrate ( $Mg(NO_3)_2 \cdot 6H_2O$ ).

In one embodiment amount of the water soluble metal salt is from 10 wt.% to 70 wt.%, preferably from 20 wt.% to 60 wt.%, and more preferably from 25 wt.% to 55 wt.% based on the total weight of the binder composition calculated as dry solids.

In another embodiment weight ratio of the water soluble metal salt to the synthetic polymer is from 0.1 to 2.2, preferably from 0.3 to 1.6, and more preferably from 0.5 to 1.3 calculated as dry solids.

The ore may be metallic ore or metallic mineral such as iron ore, taconite, magnetite, hematite, limonite, goethite, siderite, franklinite, pyrite, chalcopryite, chromite, ilmenite, chrome, copper, nickel, zinc, lead, uranium, borium or mixtures thereof.

The ore may also be non-metallic ore or non-metallic mineral, such as phosphate rock, talc, dolomite, limestone, potassium sulfate, potassium chloride, double sulfate of potassium and magnesium, magnesium oxide, calcium phosphate, carbon black, coal, coal fines, calcite, quartz or mixtures thereof.

In one embodiment the ore is selected from a group consisting of iron ore, taconite, magnetite, hematite, limonite, goethite, siderite, franklinite, pyrite,

chalcopyrite, chromite, ilmenite, chrome, copper, nickel, zinc, lead, uranium, borium, phosphate rock, talc, dolomite, limestone, potassium sulfate, potassium chloride, double sulfate of potassium and magnesium, magnesium oxide, calcium phosphate, carbon black, coal, coal fines, calcite, quartz, or any mixtures thereof.

In a preferred embodiment the ore is iron ore.

In one embodiment the binder composition is prepared by dissolving the water soluble metal salt to water followed by mixing with the synthetic polymer and/or surfactant in a form of a solution. In another embodiment the water soluble metal salt is dissolved to the synthetic polymer and/or surfactant in a form of a solution.

According to the second aspect of the present invention there is provided an ore composition. More particularly there is provided an ore composition comprising the binder composition according to the present invention and an ore(s).

The ore is selected from a group consisting of iron ore, taconite, magnetite, hematite, limonite, goethite, siderite, franklinite, pyrite, chalcopyrite, chromite, ilmenite, chrome, copper, nickel, zinc, lead, uranium, borium, phosphate rock, talc, dolomite, limestone, potassium sulfate, potassium chloride, double sulfate of potassium and magnesium, magnesium oxide, calcium phosphate, carbon black, coal, coal fines, calcite, quartz, or any mixture thereof. Preferably the ore is iron ore.

According to the third aspect of the present invention there is provided a process for preparing ore agglomerates. More particularly there is provided a process for preparing ore agglomerates comprising (i) adding the binder composition according to the present invention to fine ore particles to form a mixture; and (ii) forming the mixture into agglomerates.

The binder composition is added to fine ore particles to form a mixture. Alternatively the components of the binder composition may be added and blended separately to the ore fines. In one embodiment the water soluble metal salt is added first to the ore fines followed by addition of the synthetic polymer and/or surfactant in the form of a solution. In other embodiment the

synthetic polymer and/or surfactant in the form of a solution is added first to the ore fines followed by addition of the water soluble metal salt.

In one embodiment the binder composition is added as an aqueous solution.

5 The process steps of adding the binder composition to ore fines to form a mixture or forming the mixture into agglomerates can be carried out in the conventional or known methods in the art. In one embodiment, the process further comprises the step of mixing, stirring or agitating the mixture after the addition of the binder composition. The binder composition may be added to the ore fines prior to or during mixing of the mixture. For example, the binder  
10 composition can be blended with the ore fines by scattering the binder composition on to the ore fines as it is carried toward a mixer, such as a paddle mixer with stators.

The process may further comprise step of adding water, which may be added before, during or after the addition of the binder composition to the ore fines.  
15 The amount of water added is the amount required to bring the moisture content to the optimum level for the particular mixture. In an exemplary embodiment, the ore fines, prior to adding the binder composition, already has the desired final moisture content of about 5 to about 15%, or about 6 to about 10%, by weight based on the weight of the ore. The moisture content is the  
20 moisture as measured by heating up to 105 °C. If the ore fines initially do not contain the desired final moisture content, water may be added to increase the moisture content.

In one embodiment water is added to step (i) to raise moisture content of the ore, preferably water is added to step (i) to raise moisture content of the ore to  
25 5-15%.

In another embodiment the binder composition is diluted to the water before addition of the water to the step (i).

The forming of the mixture into agglomerates may be conducted with any known method in the art. The forming may be conducted with or without  
30 compression, by balling on a disc, or balling in a drum.

The process may further comprise a drying step in which the formed agglomerates are dried. The agglomerates may be dried for example in an oven at a

suitable temperature such as at a temperature from 70 °C to 110 °C, or at 75 °C or at 105 °C. In one embodiment the agglomerates are dried until completely dry, that is, a constant weight is reached when compounds which are volatile under the drying conditions are vaporized from the agglomerates.

- 5 In one embodiment the binder composition is added to step (i) in an amount of from 0.01 kg to 0.5 kg, preferably from 0.05 kg to 0.3 kg, more preferably from 0.1 kg to 0.2 kg per ton of the fine ore particles, calculated as dry solids.

Additional components may also be added to step (i). The additional components may be selected so that the formed agglomerates have desired features.

- 10 Examples of the additional components are coal, coke, lime, dolomite, or any mixture thereof, especially coal.

- According to the fourth aspect of the present invention there is provided a sintering process. More particularly there is provided a sintering process comprising (i) adding the binder composition according to the present  
15 invention to fine ore particles to form a mixture; (ii) forming the mixture into agglomerates; and (iii) heating the agglomerates at a temperature from 1000 °C to 1400 °C to obtain sinter.

- The binder composition is added to fine ore particles to form a mixture. Alternatively the components of the binder composition may be added and blended  
20 separately to the ore fines. In one embodiment the water soluble metal salt is added first to the ore fines followed by addition of the synthetic polymer and/or surfactant in the form of a solution. In other embodiment the synthetic polymer and/or surfactant in the form of a solution is added first to the ore fines followed by addition of the water soluble metal salt.

- 25 In one embodiment the binder composition is added as an aqueous solution.

- The process steps of adding the binder composition to ore fines to form a mixture or forming the mixture into agglomerates can be carried out in the conventional or known methods in the art. In one embodiment, the process further comprises the step of mixing, stirring or agitating the mixture after the  
30 addition of the binder composition. The binder composition may be added to the ore fines prior to or during mixing of the mixture. For example, the binder composition can be blended with the ore fines by scattering the binder compo-

sition on to the ore fines as it is carried toward a mixer, such as a paddle mixer with stators.

The process may further comprise step of adding water, which may be added before, during or after the addition of the binder composition to the ore fines.

5 The amount of water added is the amount required to bring the moisture content to the optimum level for the particular mixture. In an exemplary embodiment, the ore fines, prior to adding the binder composition, already has the desired final moisture content of about 5 to about 15%, or about 6 to about 10%, by weight based on the weight of the ore. The moisture content is the  
10 moisture as measured by heating up to 105 °C. If the ore fines initially do not contain the desired final moisture content, water may be added to increase the moisture content.

In one embodiment water is added in step (i) to raise moisture content of the ore, preferably water is added in step (i) to raise moisture content of the ore to  
15 5-15%.

In another embodiment the binder composition is diluted to the water before addition of the water to the step (i).

The forming of the mixture into agglomerates may be conducted with any known method in the art. The forming may be conducted with or without  
20 compression, by balling on a disc, or balling in a drum.

In one embodiment the binder composition is added to step (i) in an amount of from 0.01 kg to 0.5 kg, preferably from 0.05 kg to 0.3 kg, more preferably from 0.1 kg to 0.2 kg per ton of the fine ore particles, calculated as dry solids.

Additional components may also be added to step (i). The additional components may be selected so that the formed agglomerates have desired features.  
25 Examples of the additional components are coal, coke, lime, dolomite, or any mixture thereof, especially coal.

The process may further comprise a pre-heating step after step (ii) and prior step (iii) in which the formed agglomerates are dried. The agglomerates may  
30 be dried for example in an oven at a suitable temperature such as at a temperature from 70 °C to 110 °C, or at 75 °C or at 105 °C. In one embodiment the agglomerates are dried until completely dry, that is, a constant weight

is reached when compounds which are volatile under the drying conditions are vaporized from the agglomerates.

In step (iii) the agglomerates are heated at a temperature from 1000 °C to 1400 °C, preferably at a temperature from 1000 °C to 1200 °C, to obtain the sinter. The heating can be conducted by any methods known in the art. As an example, the agglomerates may be introduced to a kiln or other firing apparatus and fired in a conventional manner. As another example, the agglomerates may be heated on a sintering belt in a sintering belt process.

According to the fifth aspect of the present invention there is provided a use of the binder composition. More particularly there is provided a use of the binder composition according to the present invention as an additive in agglomerating ores.

The binder composition is used in an amount of from 0.01 kg to 0.5 kg, preferably from 0.05 kg to 0.3 kg, more preferably from 0.1 kg to 0.2 kg per ton of the particulate ore, calculated as dry solids.

Hereafter, the present invention is described in more detail and specifically with reference to the examples, which are not intended to limit the present invention.

## 20 **Examples**

### Materials

#### *Synthetic polymer in the form of solution:*

Solids content of the materials is approx. 45%.

Chem1: Sodium polyacrylate, cas: 9003-04-7, Viscosity 200 cP, MW 2600

25 Chem2: Sodium polyacrylate, cas: 9003-04-7, Viscosity 250 cP, MW 3400

Chem3: Sodium polyacrylate, cas: 9003-04-7, Viscosity 600 cP, MW 4500

Chem4: Copolymer Na salt, cas: 25987-30-8, Viscosity 800 cP, MW 6700

Chem5: Sodium polyacrylate, cas 9003-04-7, Viscosity 900 cP, MW 50000

Chem6: Polyacrylic acid, cas: 9003-04-7, Viscosity 1100 cP, MW 150000

Chem7: Copolymer Na salt, cas: 52255-49-9, viscosity 130 cP, MW 2300

Chem8: Sodium dioctyl sulfosuccinate, cas: 577-11-7, viscosity & MW not determined

- 5 Chem9: Tridekanoethoxylate, cas: 69011-36-5, viscosity & MW not determined

Chem10: Silicate/PAA blend, cas: 1344-09-8, viscosity 300 cP

*Water soluble metal salt:*

Mg(NO<sub>3</sub>)<sub>2</sub>·H<sub>2</sub>O, Magnesium Nitrate hexahydrate

- 10 *Ref polymer:*

Chem11: Nonionic polyacrylamide – High MW product (MW > 1 million)

*Preparation of binder composition according to the present invention*

- 15 Magnesium Nitrate hexahydrate was dissolved to water, and then the solution was mixed with the synthetic polymer in a form of a solution. The prepared binder composition had the following composition: 20 wt.% of Magnesium Nitrate hexahydrate, 70 wt.% of the synthetic polymer, and 10 wt.% of water.

*Preparation of iron ore agglomerates according to the present invention*

- 20 Dry or moist sinter feed mixture containing various iron ore bearing materials together with lime, dolomite, coal etc. was placed inside an Eirich R01 granulator. A batch size of 3 kg's material per test was used. The materials were mixed accordingly:

Step 1. 30 sec at 250 rpm for mixing.

- 25 Step 2. 60 sec of mixing with water addition. Water is added to raise moisture content of the ore to about 8-12%. The binder compositions are diluted to this moisture control water.

Step 3. Additional 60 sec of granulation with 250 rpm.

After agglomeration the agglomerates are dried in an oven at 105 °C until completely dry. A part of the batch is used to determine moisture content after granulation. The dry granules are placed on a stack of sieves ranging from 0.5mm to 12mm in 1mm intervals and the batch of material is sieved through manually. The weight on each sieve is recorded and based on the weights on each sieve the particle size distribution can be calculated.

Permeability was measured with a device manufactured by Kemira workshop. The wet material after granulation is placed in a cylinder approx. 22cm in height and 8cm in width. Below the cylinder is an engine that creates airflow. In the cylinder is 2 sensors 15cm from each other that measure pressure difference. Below the cylinder is a sensor that measures airflow speed. From these parameters can be calculated permeability (JPU = Japanese permeability Unit) by using the following equation. Permeability was calculated 1min and 2min after airflow. High permeability will be an advantage for sintering process. Results are disclosed in Table 1.

$$JPU = V / A(H / \Delta P)^{0.6}$$

where:  $V$ : airflow rate (Nm<sup>3</sup>/min)  
 $A$ : area (m<sup>2</sup>)  
 $H$ : height of the bed (mm)  
 $\Delta P$ : suction applied across the bed (mmH<sub>2</sub>O)

**Table 1.**

Test binder	Moisture [%]	d50	d10	d90	>10mm[%]	2-8mm[%]	<2mm [%]	JPU [1min]	JPU [2min]
Ref 6	10,62	1,79	0,17	5,60	2,0	42,8	53,3	65,4	76,2
Ref 7	10,62	1,75	0,17	5,64	1,2	43,2	53,2	46,6	48,3
Ref 8	10,55	2,64	0,24	5,88	2,2	56,2	39,2	66,6	84,4
Ref 9	10,66	2,6	0,21	6,26	2,5	53,4	41,5	62,5	63,4
<b>Average reference</b>	<b>10,61</b>	<b>2,2</b>	<b>0,20</b>	<b>5,85</b>	<b>2,0</b>	<b>48,9</b>	<b>46,8</b>	<b>60,3</b>	<b>68,1</b>
Chem3 + 30%Mg(NO <sub>3</sub> ) <sub>2</sub> (300g/t)	10,60	1,81	0,18	5,66	1,9	43,50	53,20	61,30	73,70
Chem3 + 30%Mg(NO <sub>3</sub> ) <sub>2</sub> (600g/t)	10,48	2,33	0,20	5,83	2,2	50,00	45,70	65,60	75,60
Chem3 + 30%Mg(NO <sub>3</sub> ) <sub>2</sub> (600g/t)	10,70	2,32	0,20	5,92	2,5	49,90	45,20	66,70	78,00
<b>Average Chem3 + Mg(NO<sub>3</sub>)<sub>2</sub></b>	<b>10,59</b>	<b>2,15</b>	<b>0,19</b>	<b>5,80</b>	<b>2,2</b>	<b>47,8</b>	<b>48</b>	<b>64,5</b>	<b>75,8</b>
Chem4 + 30% Mg(NO <sub>3</sub> ) <sub>2</sub> (300g/t)	10,71	2,25	0,20	5,86	2,4	43,40	46,20	66,00	79,70
Chem4 + 30% Mg(NO <sub>3</sub> ) <sub>2</sub> (600g/t)	10,81	2,55	0,21	5,96	2,8	52,50	42,30	63,20	71,40
Chem4 + 30% Mg(NO <sub>3</sub> ) <sub>2</sub> (600g/t)	10,59	2,81	0,23	6,37	3,5	55,00	38,90	81,20	99,40
<b>Average Chem4 + 30% Mg(NO<sub>3</sub>)<sub>2</sub></b>	<b>10,70</b>	<b>2,54</b>	<b>0,21</b>	<b>6,06</b>	<b>2,9</b>	<b>50,3</b>	<b>42,5</b>	<b>70,1</b>	<b>83,5</b>
Chem8 + 8% Mg(NO <sub>3</sub> ) <sub>2</sub> (200g/t)	10,60	2,33	0,18	6,32	3,0	48,20	46,40	64,70	75,40
Chem8 + 8% Mg(NO <sub>3</sub> ) <sub>2</sub> (400g/t)	10,46	1,36	0,12	5,73	2,0	39,50	56,50	73,40	87,80
<b>Average Chem8 + 8% Mg(NO<sub>3</sub>)<sub>2</sub></b>	<b>10,53</b>	<b>1,85</b>	<b>0,15</b>	<b>6,03</b>	<b>2,5</b>	<b>43,85</b>	<b>51,5</b>	<b>69,1</b>	<b>81,6</b>
Chem7 + 30% Mg(NO <sub>3</sub> ) <sub>2</sub> (260g/t)	10,72	2,5	0,21	5,30	2,4	53,20	46,10	63,10	64,20
Chem7 + 30% Mg(NO <sub>3</sub> ) <sub>2</sub> (520g/t)	10,61	2,23	0,18	5,75	1,9	49,90	46,30	65,20	80,60
Chem7 + 30% Mg(NO <sub>3</sub> ) <sub>2</sub> (600g/t)	10,67	2,19	0,17	5,98	2,7	47,50	47,90	65,20	79,00
<b>Average Chem7 + 30% Mg(NO<sub>3</sub>)<sub>2</sub></b>	<b>10,67</b>	<b>2,31</b>	<b>0,19</b>	<b>5,68</b>	<b>2,3</b>	<b>50,2</b>	<b>46,8</b>	<b>64,5</b>	<b>74,6</b>
Chem1 + 30% Mg(NO <sub>3</sub> ) <sub>2</sub> (600g/t)	10,75	3,05	0,22	7,24	3,3	54,50	38,20	77,80	93,10
Chem1 + 30% Mg(NO <sub>3</sub> ) <sub>2</sub> (600g/t)	10,60	2,05	0,16	6,44	2,3	44,90	49,40	63,30	72,20
<b>Average Chem1 + 30% Mg(NO<sub>3</sub>)<sub>2</sub></b>	<b>10,68</b>	<b>2,55</b>	<b>0,19</b>	<b>6,84</b>	<b>2,8</b>	<b>49,7</b>	<b>43,8</b>	<b>70,6</b>	<b>82,6</b>
Chem11 (300g/t)	10,80	1,25	0,14	5,21	1,1	37,00	60,40	54,80	67,60

The results in Table 1 show that dispersant and surfactant blends with Mg-nitrate agglomerates the material better in equal moisture level as the reference. The improved agglomeration results to improved permeability (JPU) values, which will result in increased sinter productivity.

As a reference also Chem11 was added. It shows really bad performance; granulation is poor (lowest d50 and d90). It generates a lot of dust (< 2mm material) and has a lower permeability value than the reference experiments.

#### 10 Sintering process according to the present invention

About 25 kg of sintering process feed mixture was used in each test. Half the material was placed in a drum with a diameter of 60cm and rotation of the drum started. At this time moisture control water was sprayed in the drum. The binder composition (Chem3 + Mg(NO<sub>3</sub>)<sub>2</sub>·H<sub>2</sub>O) was again dissolved into the moisture control water.

Agglomeration time in total was 3-4 minutes after which the material was removed and the size distribution of wet granules was measured by using sieves of 1.6mm, 3mm and 5mm. Based on these sieve fractions a granulation degree was calculated (the bigger granules the better).

The granulated material mixture was heated to about 75 °C. The heated material was placed inside a steel pot with the maximum height of 320mm and width 200mm. The material was ignited on the surface by using petrol after which vacuum was created in the pot. The coal in the charge of sinter feed  
5 started to burn and generating heat necessary for sintering. The vacuum side of the pot had a sensor to determine strength of the vacuum. The bottom of the pot had a temperature sensor that was used to determine burn trough time of coal = time of sintering.

Based on sintering speed productivity  $\text{kg}/(\text{m}^2 \times \text{min})$  was calculated. A percent-  
10 age for good quality sinter was calculated = the usable weight from the sintered charge that could be used in the process, only dust < 5mm in size was removed. After sintering the pot was emptied and the material screened to different size fractions of 40mm, 25mm, 12mm, 10mm, 8mm, 5mm and below  
15 5mm. About 5kg of material in size range of 10 to 25mm was used for the tumbling index test. About 8 kg of material in the size range of 8-25mm was used in the tumbling index test. The results were reported in percentage of material above 5 mm in size after the test. The higher the percentage, the better the result. The sinter binder pot grate results are shown in Table 2.

**Table 2.** Results of sintering pot grate tests including references and tests with sinter binder (Chem3 + Mg(NO<sub>3</sub>)<sub>2</sub>·H<sub>2</sub>O) according to the present invention

Test#	1	2	3	4	5	6	7	8	9	10	11
Additive	EXPN 026	EXPN 026	Blank	EXPN 026	Blank						
Additive dosage (rpm)	500	200		200	150	150	120	120	100	200	
Weight, kg	0,0137	0,0055		0,0056	0,0041	0,0044	0,00355	0,00355	0,00286	0,00692	
Additive type	solution	solution		solution							
Concentrate, kg											
Lime stone, kg			Agglomerate mixture with W-								
Coke, kg	Agglomerate mixture with W-5,65%	Agglomerate mixture with W-5,12%	5,62%	Agglomerate mixture with W-6,45%	Agglomerate mixture with W-4,89%	Agglomerate mixture with W-6,21%	Agglomerate mixture with W-4,36%	Agglomerate mixture with W-3,52%	Agglomerate mixture with W-5,03%	Agglomerate mixture with W-6,42%	Agglomerate mixture with W-5,50%
Return, kg	2,4	2,4	2,4	2,4	2,4	2,6	2,6	2,6	2,6	2,6	2,6
Fines, kg	1,0	1,0	0,85	0,8	1,03	0,8	1,2	1,5	1,2	1,0	1,1
Water, L	280	280	280	280	280	320	320	320	320	320	320
Height, mm	7,70	7,45	7,10	7,50	7,70	7,60	7,55	7,50	7,30	7,60	7,50
Moisture after agglomeration, %	7,05	6,80	6,40	6,90	7,00	6,40	6,55	5,10	6,60	6,90	6,70
Moisture after heating, %	79,0	85,0	79,5	80,0	80,5	82,0	84,0	77,0	80,0	79,0	80,0
Agglomerate temperature, °C											
Screen size after agglomeration, µm	+5mm	54,8	31,1	41,7	55,0	43,7	48,8	50,1	40,3	46,6	48,2
	+3mm	33,1	36,2	30,2	30,2	29,4	29,9	25,7	27,9	28,0	30,5
	+1,6mm	10,5	18,3	21,8	9,5	24,0	18,1	20,4	24,0	21,0	17,8
	-1,6mm	1,6	14,4	6,3	2,3	2,9	3,2	3,8	7,8	4,4	3,5
Agglomeration grade, %	72,1	77,0	71,5	77,6	79,1	75,5	70,4	65,5	71,9	72,6	65,0
Drum test +5mm, %	59,5	62,8	59,8	52,5	45,2	56,3	59,8	56,2	60,5	60,5	60,0
Fines +0,5mm, %	6,5	5,7	7,7	6,5	8,4	6,2	5,5	5,2	5,1	4,9	5,7
Screen size, %	+40mm	7,9	5,9	10,5	5,0	0,0	4,1	4,9	3,5	12,5	7,8
	+25mm	6,1	9,2	12,5	1,0	15,2	3,6	6,3	5,2	4,9	9,2
	+10mm	28,2	25,8	27,4	15,5	18,0	25,0	28,8	31,8	25,3	26,6
	+5mm	28,8	23,9	24,6	35,0	34,5	33,0	27,7	28,0	26,2	26,0
-5mm	29,0	35,2	25,0	47,5	32,3	34,5	32,3	31,5	31,1	30,4	
Total C in sinter, %											
Fe in sinter, %	-	53,3	53,8	54,2	53,0	53,2	-	52,6	53,7		
FeO in sinter (chemical), %	-	10,2	12,9	11,6	9,57	12,9	-	11,80	10,4		
Basicity	-	2,387	2,317	2,426	2,584	2,510	-	2,31	2,48		
C <sub>200</sub> in sinter, %	-	0,36	0,34	0,49	0,33	0,13	-	0,42	0,18		
Initial Vacuum, mm water column	140	160	175	790	610	505	505	500	550	490	560
Final Vacuum, mm water column	65	52	50	410	255	270	147	185	245	125	202
Max T, °C	193	200	212	325	290	295	230	285	185	250	265
Sintering time, min	25,0	20,3	34,0	10,6	10,0	14,2	19,4	14,4	14,8	17,7	16,3
Q sintering speed, kg/min	0,80	1,03	0,61	1,99	1,98	1,65	1,20	1,67	1,59	1,30	1,40
Q good sinter, kg/min	0,55	0,63	0,44	0,95	1,27	1,03	0,78	1,10	1,05	0,87	0,94
Q specific, kg/(m <sup>2</sup> *min)	0,44	0,56	0,13	1,09	1,05	0,95	0,69	0,97	0,92	0,74	0,80
Volume speed, m <sup>3</sup> /min	11,2	13,6	8,2	26,4	28,0	22,5	16,5	22,2	21,5	15,1	19,6

5 Table 2 shows that the sinter binder agglomerates the sinter feed mixture (consisting of concentrate, limestone, coke and return fines) well, comparing to the reference. Agglomeration grade/degree uses an equation to be able to present granule screen sizes of +5, +3, +1.6 and -1.6 with one number. The higher the value the better, since it enables good permeability or airflow through the particles.

10

The results show that with all dosage levels the sinter binder is able to provide a higher degree of granulation than the reference samples. This is the first step to achieve high productivity.

The sinter binder significantly reduces the sintering time in the pot grate tests.

15 This is directly correlated to improved productivity. The sinter binder shows that the amount of good quality sinter, kg/min, is improved significantly with both data sets when comparing to the references. This has a positive effect on the final productivity of the sintering machine kg/(m<sup>2</sup> \* min). The data in Table 2

shows that with 320mm bed level productivity  $\text{kg}/(\text{m}^2 * \text{min})$  is increased from 0.80 to 0.97, which equals an improvement of 21%.

5 The increased granule size distribution of granules provided by the sinter binder makes it possible to increase bed height from 280mm to 320mm. This is directly correlated with productivity improvement.

10 The results in Table 2 show that the sinter binder according to the present invention improves tumbling index values. In the test series with 320mm bed height tumbling index (drum test, +5mm %) is improved from 60% to 60.5 and 60.6%. This is significant when producing 6 MMT sinter per year. Also, quicker sintering (short sintering time) tends to lower sintering temperature, which reduces tumbling index. However, with the sinter binder according to the present invention this is avoided and tumbling index improves even though sinter time reduces. This effect is caused by the added magnesium nitrate to the formulation, it increases slag formation at high temperatures which  
15 increases the mechanical strength of sinter.

During the tumbling index test also harmful fines are formed (-0.5mm material) which has to be recirculated in the process. The results in Table 2 show that the sinter binder decreases the amount of formed fines. This effect can also contribute to increased production capacity of the sinter plant.

**Claims**

1. A binder composition for agglomerating fine ore particles, comprising:  
a water soluble metal salt; and  
a synthetic polymer, a surfactant, or a combination or mixture thereof;  
in a form of a solution.
2. The binder composition according to claim 1, wherein the synthetic polymer is a water soluble polymer.
3. The binder composition according to claim 2, wherein the water soluble polymer is in a form of an aqueous solution.
4. The binder composition according to any one of claims 1-3, wherein viscosity of the synthetic polymer is from 100 cP to 2000 cP, preferably from 100 cP to 1000 cP, more preferably from 200 cP to 800 cP.
5. The binder composition according to any one of claims 1-4, wherein the synthetic polymer is anionic or non-ionic synthetic polymer, preferably anionic synthetic polymer.
6. The binder composition according to any one of claims 1-5, wherein the synthetic polymer is a dispersant.
7. The binder composition according to any one of claims 1-6, wherein average molecular weight of the synthetic polymer is from 500 g/mol to 200000 g/mol, preferably from 500 g/mol to 10000 g/mol, more preferably from 2000 g/mol to 10000 g/mol.
8. The binder composition according to any one of claims 1-7, wherein the synthetic polymer is produced by solution polymerization process.
9. The binder composition according to any one of claims 1-8, wherein the synthetic polymer is a homo- or copolymer of acrylic acid, maleic acid, sulfonic acid or their salt, or a mixture thereof.
10. The binder composition according to claim 9, wherein the salt is sodium salt, ammonium salt, methyl salt, or a mixture thereof.

11. The binder composition according to any one of claims 1-10, wherein it comprises a water soluble metal salt and a salt of a synthetic polymer in a form of a solution, wherein the synthetic polymer is a homo- or copolymer of acrylic acid, maleic acid or sulfonic acid, the salt of a synthetic polymer is a sodium salt, ammonium salt or a mixture thereof, and average molecular weight of the synthetic polymer is from 500 g/mol to 200000 g/mol.

12. The binder composition according to claim 5, wherein charge density of the anionic polymer is from -3 meq/g to -12 meq/g, preferably from -7 meq/g to -11 meq/g.

13. The binder composition according to claim 6, wherein the dispersant is polyacrylate, polycarboxylate (not esters), polyacrylic acid, polyacrylamide (SPAM), or mixtures thereof.

14. The binder composition according to claim 6 or 13, wherein the dispersant is sodium polyacrylate, poly(2-acrylamido-2-methyl-1-propanesulfonic acid) (polyAMPS), or mixtures thereof.

15. The binder composition according to any one of claims 1-10 or 12-14, wherein the surfactant is

an anionic surfactant having carboxylate, sulfate, sulfonate, or phosphate group(s), or

a non-ionic surfactant having polyether groups(s) such as polyether consisting of oxyethylene unit(s); polyhydroxyl group(s); or fatty acid alcohol.

16. The binder composition according to claim 15, wherein the anionic surfactant is alkyl ether carboxylate, alkyl sulfate, alkyl ether sulfate, alkyl-benzene sulfonate, dialkyl sulfosuccinate, alkyl phosphate, or a mixture thereof, preferably sodium dioctyl sulfosuccinate.

17. The binder composition according to claim 15, wherein the non-ionic surfactant is ethoxylated linear alcohol, ethoxylated alkyl phenol, fatty acid ester, amine and amide derivatives, alkylpolyglucosides, ethylene-oxide/propyleneoxide copolymer, polyalcohol, ethoxylated polyalcohol, thiol (mercaptan) and derivatives thereof, fatty acid ethoxylate, or a mixture thereof, preferably tridekanoethoxylate.

18. The binder composition according to any one of claims 1-17, wherein the water soluble metal salt is water soluble metal(II) salt.

19. The binder composition according to any one of claims 1-18, wherein the water soluble metal salt is water soluble magnesium salt, copper salt, or a mixture thereof.

20. The binder composition according to any one of claims 1-19, wherein the water soluble metal salt is water soluble magnesium salt.

21. The binder composition according to claim 19 or 20, wherein the water soluble magnesium salt is magnesium nitrate ( $\text{Mg}(\text{NO}_3)_2$ ), preferably magnesium nitrate hexahydrate ( $\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$ ).

22. The binder composition according to any one of claims 1-21, wherein amount of the water soluble metal salt in the binder composition is from 10 wt.% to 70 wt.%, preferably from 20 wt.% to 60 wt.%, and more preferably from 25 wt.% to 55 wt.% calculated as dry solids.

23. The binder composition according to any one of claims 1-22, wherein the binder composition is in a form of an aqueous solution.

24. The binder composition according to any one of claims 1-23, wherein the ore is selected from a group consisting of iron ore, taconite, magnetite, hematite, limonite, goethite, siderite, franklinite, pyrite, chalcopryrite, chromite, ilmenite, chrome, copper, nickel, zinc, lead, uranium, borium, phosphate rock, talc, dolomite, limestone, potassium sulfate, potassium chloride, double sulfate of potassium and magnesium, magnesium oxide, calcium phosphate, carbon black, coal, coal fines, calcite, quartz, or any mixture thereof.

25. The binder composition according to any one of claims 1-24, wherein the ore is iron ore.

26. An ore composition comprising the binder composition according to any one of claims 1-25 and an ore selected from a group consisting of iron ore, taconite, magnetite, hematite, limonite, goethite, siderite, franklinite, pyrite, chalcopryrite, chromite, ilmenite, chrome, copper, nickel, zinc, lead, uranium, borium, phosphate rock, talc, dolomite, limestone, potassium sulfate, potassium chloride, double sulfate of potassium and magnesium, magnesium

oxide, calcium phosphate, carbon black, coal, coal fines, calcite, quartz, or any mixture thereof.

27. The ore composition according to claim 26, wherein the ore is iron ore.

28. A process for preparing ore agglomerates comprising

(i) adding the binder composition according to any one of claims 1-25 to fine ore particles to form a mixture; and

(ii) forming the mixture into agglomerates.

29. The process according to claim 28, wherein the binder composition is added in an amount of from 0.01 kg to 0.5 kg, preferably from 0.05 kg to 0.3 kg, more preferably from 0.1 kg to 0.2 kg per ton of the particulate ore.

30. The process according to claim 28 or 29, wherein the binder composition is added as an aqueous solution.

31. The process according to any one of claims 28-30, wherein additionally coal, coke, lime, dolomite, or any mixture thereof, preferably coal, is added to step (i).

32. A sintering process comprising

(i) adding the binder composition according to any one of claims 1-25 to fine ore particles to form a mixture;

(ii) forming the mixture into agglomerates; and

(iii) heating the agglomerates at a temperature from 1000 °C to 1400 °C to obtain sinter.

33. The process according to claim 32, wherein the binder composition is added in an amount of from 0.01 kg to 0.5 kg, preferably from 0.05 kg to 0.3 kg, more preferably from 0.1 kg to 0.2 kg per ton of the particulate ore.

34. The process according to claim 32 or 33, wherein the binder composition is added as an aqueous solution.

35. The process according to any one of claims 32-34, wherein additionally coal, coke, lime, dolomite, or any mixture thereof, preferably coal, is added to step (i).

36. Use of the binder composition according to any one of claims 1-25 as an additive in agglomerating ores.

37. The use according to claim 36, wherein the binder composition is used in an amount of from 0.01 kg to 0.5 kg, preferably from 0.05 kg to 0.3 kg, more preferably from 0.1 kg to 0.2 kg per ton of the particulate ore.

INTERNATIONAL SEARCH REPORT

International application No  
PCT/FI2017/050365

A. CLASSIFICATION OF SUBJECT MATTER  
INV. C22B1/16  
ADD.  
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED  
Minimum documentation searched (classification system followed by classification symbols)  
C22B

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 practicable, search terms used)  
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3 893 847 A (DERRICK ARTHUR PERCY) 8 July 1975 (1975-07-08)  c. 1, l. 9-11, l. 62 to c. 2, l. 32; c. 3, l. 2-6; c. 8: "TABLE 6"; claims 1-3N "TABLE 1"  -----	1-6,9, 10,13, 23-30, 32-34, 36,37
X	WO 99/60175 A1 (INTERBLEND INVESTMENTS PROPRIE [ZA]; MOODY JOHN RUTHERFORD [ZA]) 25 November 1999 (1999-11-25)  p. 3, l. 7-16; p. 5  -----	1-3,5,9, 10,13, 18-20, 22-28,36
A	US 4 802 914 A (ROSEN MEYER R [US] ET AL) 7 February 1989 (1989-02-07) the whole document  -----	1-37
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Further documents are listed in the continuation of Box C.

See patent family annex.

\* Special categories of cited documents :

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- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
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Date of the actual completion of the international search  14 July 2017	Date of mailing of the international search report  27/07/2017
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Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer  Radeck, Stephanie
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## INTERNATIONAL SEARCH REPORT

International application No  
PCT/FI2017/050365

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 028 263 A (BURDICK CHARLES L [US]) 2 July 1991 (1991-07-02) the whole document	1-37
A	----- EP 1 541 700 A1 (NIPPON STEEL CORP [JP]; NIPPON CATALYTIC CHEM IND [JP]) 15 June 2005 (2005-06-15) the whole document -----	1-37

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/FI2017/050365

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