

A ROTARY KILN, A SCREENING ASSEMBLY FOR A ROTARY KILN, AND A METHOD FOR SINTERING GRANULES

FIELD OF INVENTION

- 5 The present invention relates broadly to a rotary kiln, to a screening assembly for a rotary kiln, and to a method for sintering granules in particular to a rotary kiln, to an assembly for a rotatory kiln, and to a method for screening granulate/aggregate in a rotary kiln, in particular to optimise sintering time.

10 BACKGROUND

Any mention and/or discussion of prior art throughout the specification should not be considered, in any way, as an admission that this prior art is well known or forms part of common general knowledge in the field.

- 15 A rotary kiln is typically used to produce lightweight aggregate by sintering the appropriate minerals at high temperature. The sintering temperature can vary between 700°C and 1350°C depending on the minerals used, the flux and the bloating agents. In the process of the production of the lightweight aggregates, the raw materials are first mixed with the appropriate bonding, flux and bloating agents and thereafter granulated into green granules. These green granules are pre-heated to remove the moisture before sintering in the rotary kiln.

- 20 The granulation process often produces green granulates of various sizes. These green granules are then discharged into the rotary kiln that is inclined and rotating. The retention time of the green granules in the rotary kiln is governed by the length, inclination and rotating speed. However, following discharge into existing rotary kilns, in the sintering all these green granules of different sizes are sintered for the same time in the rotary kiln, i.e. subjecting them to the same temperature and retention time. This will subject some (smaller) green granules to be over-exposed while others (larger) green granules are under-exposed in terms of sintering time. The current practice has been to expose these green granules to longer period to prevent underexposure that may lead to not fully expanded aggregates. However, this means additional sintering time which inevitably increases production time and sintering cost.

- 30 An alternative to circumvent this problem would be to screen the green granules to various sizes first, prior to discharge into the kiln for sintering, and setting different temperatures and/or retention times between different sintering runs for the respective different sizes. However, this involves additional processes that result in additional logistics, cost and time.

Embodiments of the present invention seek to address at least one of the above problems.

SUMMARY

In accordance with a first aspect of the present invention, there is provided a rotary kiln for sintering of green granules to produce lightweight aggregates, comprising:

an inner surface defining a sintering chamber; and

5 a plurality of screening elements disposed along the sintering chamber;

wherein each screening element is configured to define a plurality of gaps at or near respective portions of an outer edge of each screening element adjacent the inner surface of the rotary kiln, with the gaps increasing from one edge portion to another in a direction along the outer edge of each screening element that is opposite to the rotational direction of the rotary kiln; and

wherein the plurality of screening elements are configured in an offset manner such that none of the gaps of the same size overlap between directly adjacent pairs of the plurality of screening elements.

15 In accordance with a second aspect of the present invention, there is provided a screening assembly for a rotary kiln for sintering of green granules to produce lightweight aggregates, comprising a plurality of screening elements configured for being disposed along a sintering chamber defined by an inner surface of the rotary kiln;

wherein each screening element is configured to define a plurality of gaps at or near respective portions of an outer edge of each screening element adjacent the inner surface of the rotary kiln, with the gaps increasing from one edge portion to another in a direction that is opposite to the rotational direction of the rotary kiln; and

wherein the plurality of screening elements are configured to be arranged in an offset manner in the sintering chamber such that none of the gaps of the same size overlap between directly adjacent pairs of the plurality of screening elements.

25 In accordance with a third aspect of the present invention, there is provided a method of sintering of green granules to produce lightweight aggregates, comprising screening the granules during the sintering process.

BRIEF DESCRIPTION OF THE DRAWINGS

30 Embodiments of the invention will be better understood and readily apparent to one of ordinary skill in the art from the following written description, by way of example only, and in conjunction with the drawings, in which:

FIG 1 shows a schematic drawing of a rotary kiln according to an example embodiment of the present invention in a frontal (material input) isometric view with break-out of the rotary kiln showing the assembly of the plates and the steel stud inside.

FIG 2 shows a schematic drawing of the rotary kiln of FIG 1 in isometric view as seen from the back (material output) with break-out of the rotary kiln showing the assembly of the plates and the steel stud inside.

FIG 3 shows a schematic drawing of the rotary kiln of FIG 1 in sectional view showing the orientation of one plate of the assembly of the plates and the steel stud inside to demonstrate the increase in the gap between the plate edge and the inner face of the rotary kiln.

FIG 4 shows schematic drawings illustrating the sequence of the screening plates' orientation in the rotary kiln of FIG 1.

DETAILED DESCRIPTION

In an example embodiment of the present invention, a method of sintering of green granules to produce lightweight aggregates is provided which comprises screening the granules during the sintering process. In an example embodiment, this is implemented by providing a screening assembly that is assembled into the rotary kiln, embodied either as a modified rotary kiln according to an example embodiment or as a screening assembly according to an example embodiment for retro-fitting to an existing kiln. The screening assembly automatically segregates the green granules during sintering such that they are subjected to the appropriate sintering time according to size. This is advantageously achieved without any moving parts inside the rotary kiln, according to example embodiment. Embodiments of the present invention can preferably provide a continuous screening and sintering process.

As is understood by a person skilled in the art, the sintering of aggregates in the rotary kiln depends on the temperature and the retention time of the aggregates in the kiln. The overall retention time is controlled by the length, inclination and rotation speed of the rotary kiln. Different types and sizes of aggregates will need different temperature and retention time to fully bloat and sinter. Any shortfall in temperature or retention time will result in un-bloated or partially sintered aggregates.

On the other hand, as mentioned in the background section, when the green aggregates are produced for sintering, it is not possible to produce single size granules. The sizes will vary within a small range depending on the granulation technique and equipment used. Therefore, the sintering and bloating is often not optimized since all the different size green granules are sintered in the same rotary kiln at the same time, since in practice the process of screening the green granules into different sizes first and then sintering them separately involves too much time and logistics, and hence cost.

In example embodiments of the present invention, the rotary kiln is partitioned with specially designed plate structures at prescribed intervals. The plate structures are incorporated with, or define slots that will allow smaller granules to pass through but retain the larger granules. By varying the sizes of these slots and positioning them in the appropriate location in the rotary kiln, the movements of the various sizes of the granules through the rotary kiln can be

controlled. The inclusion of these plate structures advantageously enables screening of the aggregates within the rotary kiln and accord higher retention time for larger aggregates and lower retention time for the smaller aggregates. In doing so, the smaller aggregates will be sintered and bloated for a shorter period while the larger aggregates will be sintered and bloated for a longer period. This reduces the overall sintering time and hence saves energy, time, and money, and at the same time improves the quality of the sintered aggregates.

An example embodiment of the present invention and its operations will now be described with reference to FIGS 1 to 9. Of course, it will be appreciated by those skilled in the art that variations and/or modifications may be made without departing from the spirit and scope of the present invention.

In FIGS 1 and 2, there are shown schematic drawings in the isometric view of a kiln 1 according to an example embodiment of the present invention, from the front (material input) and from the back (material output), respectively. Shown in both the figures, numeral 1 is the rotary kiln according to an example embodiment, inside which the screening plates e.g. 14 are arranged at prescribed intervals. The screening plates e.g. 14 in this non-limiting example embodiment are secured by six steel studs e.g. 3 that are secured to end plates 4 (material output end) and 5 (material input end). It is noted that screening plates e.g. 14 and the end plates 4 and 5 are assembled as one entity with the kiln 1. During rotation, both the kiln 1 and the plates e.g. 14, 4, 5 rotate in unison. This is achieved by fixing the end plates 4 and 5 to the respective ends of the rotary kiln 1 body, e.g. by welding and/or bolting. The number of steel studs e.g. 3 and their position can be varied in various example embodiments, noting that the objective of the steel studs e.g. 3 is to secure all the plates e.g. 14, 4, 5 to the body of the rotary kiln 1. End plate 4 is connected to the output end of the rotary kiln 1 while the end plate 5 is connected to the input end of the rotary kiln 1. All the plates e.g. 14, 4, 5 will rotate together with the rotary kiln 1. Accordingly, the end plates 4, 5 are configured for securing a plurality of mounting rods, here in the form of the steel studs e.g. 3, for the screening elements, here in the form of screening plates e.g. 14. Each screening plate e.g. 14 is configured for engaging the steel studs e.g. 3, here by providing holes e.g. 24 through which the steel studs e.g. 3 are fed, to mount the screening plates e.g. 14 along the sintering chamber 32. The end plates 5, 4 disposed at the material input end and the material output end of the kiln 1, respectively, each comprise an opening 26, 28 for input and output of the material, respectively.

The kiln 1 can be heated by using heating elements (not shown) on the exterior of the kiln 1 and powered by electricity. Alternatively, hot gas can be blown from the material output end of the rotary kiln 1 and waste heat is collected at the material input end to be circulated for other process(es). As will be appreciated by a person skilled in the art, rotary kilns are mostly made from refractory-lined steel shells, noting that for low temperature sintering, say up to 1200 degC, alloy steel can also be used without refractory lining.

In FIG 3, there is shown a schematic drawing showing one screening plate 14 in the rotary kiln 1. The gaps, 6, 7, 8, 9 and 10, between the inner face of the rotary kiln 1 and sections e.g. 34 of the outer edge of the screening plate 14 increases in the clockwise direction starting from

gap 6 to gap 10. In this illustration, the increase in gap distance is of equal increment over every 60° sector of the kiln 1 cross section. The increase in the gap distance can be gradual or incremental and the dimensions of the gaps will depend on the sizes of the aggregate. The plate 14 is also provided with an opening, 11, to allow any oversized aggregates or other large agglomeration of aggregates to pass through. Not allowing these to pass through can lead to clogging up of the aggregate flow in the rotary kiln 1. Accordingly, each screening element, here in the form of screening plates e.g. 14, comprises a cut-out portion creating the opening 11 and allowing granules larger than a largest one of the gaps 6-10 to pass through.

In the illustration in FIGS 1 to 3, the rotary kiln 1 rotates in the anti-clockwise direction. In general, the rotation direction of the rotary kiln 1 is opposite to the direction of the gap increment according to example embodiments.

In FIG 4, schematic drawings illustrating one sequence of the screening plates' orientations in the rotary kiln 1. After the end plate 5 (see FIGS 1 and 2), plate 12 follows, followed by plates 13, 14, 15, 16 and 17. Thereafter, the sequence of plates 12 to 17 is repeated until the whole length of the rotary kiln 1 is filled. The number of screening plates required depends on the interval dimension between the screening plates and the length of the rotary kiln 1. The interval dimension between the screening plates and the length of the rotary kiln 1, on the other hand, can be derived from the production capacity and the sintering retention time required. Accordingly, the rotary kiln 1 comprises sets of the plurality of screening elements, here in the form of screening plates 12-17, disposed along the sintering chamber 32. A sequence of the plurality of screening plates 12-17, and their respective orientations are the same between the sets.

As described above, the rotary kiln 1 has an inner surface 30 defining the sintering chamber 32 and with a plurality of screening elements, here in the form of screening plates 12-17, disposed along the sintering chamber 32. Each screening plate 12-17, is configured to define a plurality of gaps 6-10 between respective portions e.g. 34 of an outer edge thereof and the inner surface 30 of the kiln 1, with the gaps 6-10 increasing from one edge portion e.g. 34 to another e.g. 36 in a direction along the outer edge that is opposite to the rotational direction of the rotary kiln 1. The screening plates 12-17 are configured in an offset manner such that none of the gaps 6-10 of the same size overlap between directly adjacent pairs e.g. 12, 13.

It is noted that having the screening plates configured with hollow sections in the middle is advantageous for even heat distribution. As mentioned above, in some rotary kilns, hot air is blown from the material output end to the material input end, for example.

For illustration purpose, it is assumed that the aggregate sizes to be sintered according to an example embodiment may range from 1mm to 10mm. The size of gaps 6, 7, 8, 9 and 10 (see FIG. 3) in such an example embodiment ranges from 2, 4, 6, 8 and 10mm, by way of example, not limitation. In the sintering operation, the green granules are fed into the kiln through the input end plate 5 (see FIGS 1 and 2). Assuming at the feeding of green granules, the first intermediate plate 12 is at the orientation as shown in FIG 4. Since plate 12 is with the opening 11 at the base, substantially all the green granules will proceed to the next intermediate plate

13. At this juncture, green granules smaller than 2mm will pass through the gap (indicated at numeral 6 in FIG 4), with the rest of the green granules being held back. The green granules smaller than 2mm will go through all the intermediate plates, given the relative orientation of the screening plates as shown in FIG. 4, i.e. larger gaps 7-10 at the bottom of the respective screening plates 14-17, until it reaches the output end plate 4 before being discharge out. This will then give green granules smaller than 2mm the shortest retention time in the rotary kiln.

On the other hand, looking at the 10mm green granules, they will be retained by screening plate 13 until the kiln 1, and hence the screening plates, rotate and screening plate 13 reaches the orientation illustrated for screening plate 17 in FIG. 4, before passing through to the next screening plate 14. Therefore, the 10mm green granules will be retained for the longest period. In line with this explanation, the retention time of the aggregates will depend on their size; the smallest aggregates being retained the shortest time while the largest aggregates being retained the longest time. This is in line with the objective of embodiments of the present invention, that is to allocate shorter time to sinter smaller aggregates and longer time to sinter larger aggregates in the same rotary kiln without having to segregate the aggregates into various sizes beforehand.

For illustration only, assume the kiln 1 of length 12 metres is rotating at 10 rpm and inclined at 3 degrees from horizontal. This will result in about 3mins for the 2mm green aggregates to travel unimpeded from one end of the kiln to the other, whereas the larger 10mm aggregates will take about 15mins travel from one end to the other due to the impediment according to an example embodiment.

It is noted that the feed level of the kiln is such that no spill over is likely to happen. This is not a drawback compared to existing kilns, given that the feed has to be in any event limited to ensure sufficient heat transfer for sintering, as will be appreciated by a person skilled in the art.

It is noted that the inclination and rotation speed is preferably set to suit the smallest granules sintering retention time.

It is noted that the dimension and number of increment of gaps, the interval between screening plates, and the orientation of the screening plates can be arranged in various different ways in various example embodiments to meet the abovementioned objective. The other factors governing the sintering time are the rotational speed, inclination, and length of the rotary kiln in various example embodiments. For illustration only, the dimensions of the rotary kiln may vary from about 12m long and 1.2m wide to about 80m long and 6m wide. The inclination is typically within about 5 degree, whereas the rotational speed varies from about 10 rpm for a small kiln to about 0.5 rpm for larger kilns.

As described above, in an example embodiment of the present invention, a method of sintering of green granules to produce lightweight aggregates is provided which comprises screening the granules during the sintering process. In an example embodiment, this is implemented by providing a screening assembly that is assembled into the rotary kiln, embodied either as a modified rotary kiln 1 according to an example embodiment or as a screening assembly

comprising the plurality of screening elements, e.g in the form of the screening plates 12-17, configured for being disposed along a sintering chamber defined by an inner surface of an existing kiln, for retro-fitting.

5 It is noted that the gaps through which the granules pass are created by a spacing from the inner surface of the kiln 1 body in the example embodiment described. However, it is noted that in a different embodiment, the "gap" can be created entirely on or in the screening plates. While the bottom portion of the screening plate around the gap in such an embodiment that comes in contact with the inner surface of the kilns may form a ledge that may impede the flow of the granules, a suitably small 'ledge' height may still allow the granules to cross over, especially if
10 the granules to be sintered are large.

In one embodiment, a rotary kiln for sintering of green granules to produce lightweight aggregates is provided, comprising an inner surface defining a sintering chamber; and a plurality of screening elements disposed along the sintering chamber; wherein each screening element is configured to define a plurality of gaps at or near respective portions of an outer
15 edge of each screening element adjacent the inner surface of the rotary kiln, with the gaps increasing from one edge portion to another in a direction along the outer edge of each screening element that is opposite to the rotational direction of the rotary kiln; and wherein the plurality of screening elements are configured in an offset manner such that none of the gaps of the same size overlap between directly adjacent pairs of the plurality of screening elements.

20 The rotary kiln may comprise sets of the plurality of screening elements disposed along the sintering chamber. A sequence of the plurality of screening elements and their respective orientations may be the same between the sets.

The rotary kilns may comprise first and second end plates disposed at a material input end and a material output end of the kiln, respectively, each of the first and second plates comprising
25 an opening for input and output of the material, respectively. The first and second end plates may be configured for securing a plurality of mounting rods for the screening elements. Each screening element may be configured for engaging the mounting rods to mount the screening elements along the sintering chamber.

30 Each of the plurality of screening elements may comprise a central opening. Each of the plurality of screening elements may be substantially ring shaped.

Each screening element may comprise a cut-out portion allowing granules larger than a largest one of the gaps to pass through.

In one embodiment a screening assembly for a rotary kiln for sintering of green granules to produce lightweight aggregates is provided, comprising a plurality of screening elements
35 configured for being disposed along a sintering chamber defined by an inner surface of the rotary kiln; wherein each screening element is configured to define a plurality of gaps at or near respective portions of an outer edge of each screening element adjacent the inner surface of the rotary kiln, with the gaps increasing from one edge portion to another in a direction that

is opposite to the rotational direction of the rotary kiln; and wherein the plurality of screening elements are configured to be arranged in an offset manner in the sintering chamber such that none of the gaps of the same size overlap between directly adjacent pairs of the plurality of screening elements.

- 5 The screening assembly may comprise sets of the plurality of screening elements configured for being disposed along the sintering chamber. The sets may be configured such that a sequence of the plurality of screening elements and their respective orientations are the same between the sets.

10 The screening assembly may comprise first and second end plates configured for being disposed at a material input end and a material output end of the kiln, respectively, each of the first and second plates comprising an opening for input and output of the material, respectively. The first and second end plates may be configured for securing a plurality of mounting rods for the screening elements. Each screening element may be configured for engaging the mounting rods to mount the screening elements along the sintering chamber.

- 15 Each of the plurality of screening elements may comprise a central opening. Each of the plurality of screening elements may be substantially ring shaped.

Each screening element may comprise a cut-out portion allowing granules larger than a largest one of the gaps to pass through.

- 20 In one embodiment, a method of sintering of green granules to produce lightweight aggregates is provided, comprising screening the granules during the sintering process.

The method may comprise using the rotary kiln or the screening assembly according to an example embodiment.

25 The above description of illustrated embodiments of the systems and methods is not intended to be exhaustive or to limit the systems and methods to the precise forms disclosed. While specific embodiments of, and examples for, the systems components and methods are described herein for illustrative purposes, various equivalent modifications are possible within the scope of the systems, components and methods, as those skilled in the relevant art will recognize. The teachings of the systems and methods provided herein can be applied to other processing systems and methods, not only for the systems and methods described above.

- 30 It will be appreciated by a person skilled in the art that numerous variations and/or modifications may be made to the present invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects to be illustrative and not restrictive. Also, the invention includes any combination of features described for different embodiments,
35 including in the summary section, even if the feature or combination of features is not explicitly specified in the claims or the detailed description of the present embodiments.

In general, in the following claims, the terms used should not be construed to limit the systems and methods to the specific embodiments disclosed in the specification and the claims, but should be construed to include all processing systems that operate under the claims. Accordingly, the systems and methods are not limited by the disclosure, but instead the scope of the systems and methods is to be determined entirely by the claims.

Unless the context clearly requires otherwise, throughout the description and the claims, the words "comprise," "comprising," and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in a sense of "including, but not limited to." Words using the singular or plural number also include the plural or singular number respectively. Additionally, the words "herein," "hereunder," "above," "below," and words of similar import refer to this application as a whole and not to any particular portions of this application. When the word "or" is used in reference to a list of two or more items, that word covers all of the following interpretations of the word: any of the items in the list, all of the items in the list and any combination of the items in the list.

CLAIMS

1. A rotary kiln for sintering of green granules to produce lightweight aggregates, comprising:

an inner surface defining a sintering chamber; and

5 a plurality of screening elements disposed along the sintering chamber;

wherein each screening element is configured to define a plurality of gaps at or near respective portions of an outer edge of each screening element adjacent the inner surface of the rotary kiln, with the gaps increasing from one edge portion to another in a direction along the outer edge of each screening element that is opposite to the rotational direction of the rotary kiln; and

wherein the plurality of screening elements are configured in an offset manner such that none of the gaps of the same size overlap between directly adjacent pairs of the plurality of screening elements.

2. The rotary kiln of claim 1, comprising sets of the plurality of screening elements disposed along the sintering chamber.

3. The rotary kiln of claim 2, wherein a sequence of the plurality of screening elements and their respective orientations are the same between the sets.

4. The rotary kilns of any one of claims 1 to 3, comprising first and second end plates disposed at a material input end and a material output end of the kiln, respectively, each of the first and second plates comprising an opening for input and output of the material, respectively.

5. The rotary kiln of claim 4, wherein the first and second end plates are configured for securing a plurality of mounting rods for the screening elements.

6. The rotary kiln of claim 5, wherein each screening element is configured for engaging the mounting rods to mount the screening elements along the sintering chamber.

7. The rotary kiln of any one of claims 1 to 6, wherein each of the plurality of screening elements comprises a central opening.

8. The rotary kiln of claim 7, wherein each of the plurality of screening elements is substantially ring shaped.

9. The rotary kiln of any one of claims 1 to 8, wherein each screening element comprises a cut-out portion allowing granules larger than a largest one of the gaps to pass through.

10. A screening assembly for a rotary kiln for sintering of green granules to produce lightweight aggregates, comprising a plurality of screening elements configured for being disposed along a sintering chamber defined by an inner surface of the rotary kiln;

wherein each screening element is configured to define a plurality of gaps at or near respective portions of an outer edge of each screening element adjacent the inner surface of the rotary kiln, with the gaps increasing from one edge portion to another in a direction that is opposite to the rotational direction of the rotary kiln; and

- 5 wherein the plurality of screening elements are configured to be arranged in an offset manner in the sintering chamber such that none of the gaps of the same size overlap between directly adjacent pairs of the plurality of screening elements.

11. The screening assembly of claim 10, comprising sets of the plurality of screening elements configured for being disposed along the sintering chamber.

- 10 12. The screening assembly of claim 11, wherein the sets are configured such that a sequence of the plurality of screening elements and their respective orientations are the same between the sets.

13. The screening assembly of any one of claims 10 to 12, comprising first and second end plates configured for being disposed at a material input end and a material output end of the
15 kiln, respectively, each of the first and second plates comprising an opening for input and output of the material, respectively.

14. The screening assembly of claim 13, wherein the first and second end plates are configured for securing a plurality of mounting rods for the screening elements.

15. The screening assembly of claim 14, wherein each screening element is configured for
20 engaging the mounting rods to mount the screening elements along the sintering chamber.

16. The screening assembly of any one of claims 10 to 15, wherein each of the plurality of screening elements comprises a central opening.

17. The screening assembly of claim 16, wherein each of the plurality of screening elements is substantially ring shaped.

- 25 18. The screening assembly of any one of claims 10 to 17, wherein each screening element comprises a cut-out portion allowing granules larger than a largest one of the gaps to pass through.

19. A method of sintering of green granules to produce lightweight aggregates, comprising screening the granules during the sintering process using the rotary kiln of any one of claims 1
30 to 9 or the screening assembly of any one of claims 10 to 18.