APPARATUS AND METHOD FOR SEAFLOOR STOCKPILING

Inventors: Glen Robert Jones, Milton (AU); Daal Hallam Jaffers, Milton (AU); Roland Gunter Berndt, Milton (AU); Paul David Griffiths, Wallsend (GB); David Edward Milburn, Wallsend (GB)

Assignee: NAUTILUS MINERALS PACIFIC PTY LTD, Milton, Queensland (AU)

Publication Classification

- Int. Cl. E21C 50/00 (2006.01)
- E02F 5/00 (2006.01)
- U.S. Cl. E21C 50/00 (2013.01); E02F 5/006 (2013.01)
- CPC 37/314

ABSTRACT

An apparatus for seafloor stockpiling that has a slurry inlet that receives slurry from a seafloor tool via a slurry transfer pipe and walls that, together with the seafloor, define a cavity having a stockpiling volume. The walls are made substantially of a water permeable material, such as a filter fabric or geotextile, that captures and contains seafloor material present in slurry received from the slurry inlet, while permitting egress of water from the slurry. In a preferred form the seafloor stockpiling device is a hood with an open bottom that is located on a seafloor surface.
APPROACH AND METHOD FOR SEAFLOOR STOCKPILING

TECHNICAL FIELD

[0001] The present invention relates generally to underwater mining, and in particular relates to an apparatus for seafloor stockpiling. In particular the invention relates, but is not limited, to a seafloor stockpiling device which receives seafloor material, typically ore slurry, from at least one seafloor tool, and from which the seafloor material can be gathered for transfer to a surface vessel.

BACKGROUND OF THE INVENTION

[0002] Seabed excavation is often performed by dredging, for example to retrieve valuable alluvial placer deposits or to keep waterways navigable. Suction dredging involves positioning a gathering end of a pipe or tube close to the seabed material to be excavated, and using a surface pump to generate a negative differential pressure to suck water and nearby mobile seafloor sediment up the pipe. Cutter suction dredging further provides a cutter head at or near the suction inlet to release compacted soils, gravels or even hard rock, to be sucked up the tube. Large cutter suction dredges can apply tens of thousands of kilowatts of cutting power. Other seabed dredging techniques include auger suction, jet lift, air lift and bucket dredging.

[0003] Most dredging equipment typically operates only to depths of tens of metres, with even very large dredges having maximum dredging depths of little more than one hundred metres. Dredging is thus usually limited to relatively shallow water.

[0004] Subsea boreholes such as oil wells can operate in deeper water of up to several thousand metres depth. However, subsea borehole mining technology does not enable seafloor mining.

[0005] Any discussion of documents, acts, materials, devices, articles or the like or the like which has been included in the present specification is solely for the purpose of providing a context for the present invention. It is not to be taken as an admission that any or all of these matters form part of the prior art base or were common general knowledge in the field relevant to the present invention as it existed before the priority date of each claim of this application.

[0006] Throughout this specification the word “comprise”, or variations such as “comprises” or “comprising”, will be understood to imply the inclusion of a stated element, integer or step, or group of elements, integers or steps, but not the exclusion of any other element, integer or step, or group of elements, integers or steps.

SUMMARY OF THE INVENTION

[0007] According to an aspect the present invention provides a seafloor stockpiling device that is located on the seafloor in use, the device comprising:

[0008] a slurry inlet for attachment of a slurry transfer pipe and for receiving slurry from a seafloor tool; and

[0009] walls that substantially define a cavity having a stockpiling volume, the walls being configured to capture and contain seafloor material present in the slurry in the device while permitting egress of water present in the slurry from the device.

[0010] Preferably, the seafloor stockpiling device is a hood. Preferably the hood has an open bottom. Preferably the cavity is defined by the walls together with a seafloor surface on which the seafloor stockpiling device is located. Preferably the hood is relocatable and at least a portion of the walls are moveable sections that reduce drag loads during movement of the seafloor stockpiling device. The movement may be deployment, seafloor relocation, or recovery of the seafloor stockpiling device.

[0011] Preferably, at least a portion of the walls are water permeable. Preferably at least a portion of the walls comprise a filter material, such as a geotextile, and/or a filter structure, such as an inclined plate or tube settler, which permits egress of water while containing the desired seafloor material. In a preferred form the walls of the seafloor stockpiling device comprise both a filter material portion and a filter structure portion, preferably a geotextile portion and an inclined plate or tube settler portion, respectively.

[0012] The filter material is preferably reversibly mounted such that reversing the mounting of the filter material causes an inward facing surface of the filter material to become outward facing. Reversible mounting of the filter material may present a number of advantages, for example the ability for the filter material to be selectively cleaned when fine seafloor material accumulates on the filter material, as further stockpiling operations will tend to flush such accumulations off the outside surface.

[0013] The seafloor stockpiling device preferably further comprises a friction reduction mechanism which may be utilised to reduce static friction (stiction) between the seafloor stockpiling device and a seafloor surface on which the seafloor stockpiling device is located when lifting the device from the seafloor. The friction reduction mechanism may comprise one or more fluid outlets adjacent a bottom portion of the device. The fluid outlets are preferably directed generally towards the seafloor. In use, the fluid outlets preferably fluidise sediment and seafloor material adjacent the seafloor stockpiling device.

[0014] The friction reduction mechanism may alternatively, or additionally, comprise movable walls. The movable walls are preferably contained inside the walls of the device and enclose seafloor material contained within the device. The movable walls preferably pivot relative to the walls of the device during lifting of the device. As the movable walls pivot they preferably swing away from the seafloor material contained within the device.

[0015] The device preferably has at least one lifting attachment for lifting and manoeuvring the device. The lifting attachment is preferably engaged with a movement system that can at least lift the device. An offset lifting attachment which is offset from a central axis of the device, preferably located on or adjacent an outer edge of the device, may be provided. The offset lifting attachment preferably causes the device to be lifted on an angle during relocation of the device.

[0016] Preferably the seafloor stockpiling device is formed from at least two modules configured for separate deployment from a surface vessel and for underwater interconnection. The maximum deployment capacity of surface vessel deployment systems may present a constraint to the size of the seafloor stockpiling device and, accordingly, in some embodiments the seafloor stockpiling device is formed in two or more modules configured for separate surface deployment, and configured for interconnection once submerged and/or on the seafloor. For example, such a modular seafloor stockpiling...
device may, in some embodiments, be up to 25 m in diameter and up to 100T submerged weight once formed from the two or more modules.

In embodiments of the invention, the seafloor stockpiling device may comprise a stockpile removal device enabling material stockpiled within the seafloor stockpiling device to be removed in slurry form. The stockpile removal device may comprise an opening port, such as a door in the seafloor stockpiling device, which when open permits a boom mounted suction inlet of a seafloor machine to be introduced into the seafloor stockpiling device to gather stockpiled material, preferably in slurry form, and which when closed restrains stockpiled material. Alternatively or additionally the stockpile removal device of the seafloor stockpiling device may comprise a suction inlet and slurry transfer pipe mounted on and extending into the seafloor stockpiling device, so that the suction inlet of the seafloor stockpiling device is placed in a suitable position to mobilise and extract stockpiled material.

Such embodiments of the present invention recognise that slurry flow rates desired for capturing seafloor material can be significantly different to the slurry flow rates desired for lifting slurry to a surface vessel, such as by a riser and lift system, and thus provides for decoupling of these flow rates by use of a seafloor stockpiling device. The respective flow rates may thus be separately optimised. For example, a slurry flow rate into the seafloor stockpiling device may for example be about 3,000 m³/hour, with an ore concentration of about 3%, while a slurry flow rate to the surface vessel may be around 1,000 m³/hour at an average ore concentration of about 12%.

In embodiments of the invention, the seafloor stockpiling device is preferably configured such that, when positioned on a relatively flat portion of the seafloor, the seafloor stockpiling device forms a hood which completely encloses a stockpiling volume in a manner to minimise the loss of slow-settling fine particles (referred to herein as "fines"). In such embodiments, to accommodate large volumes of slurry inflow, the hood preferably permits the egress of water from the stockpiling volume so as to filter and capture the seafloor material from the slurry. To this end, preferably a significant surface area of the walls of the hood are formed of filter material which contains fines while permitting egress of water from the hood. A grade of the filter material, being a dimension below which solid particles cannot pass through the filter material, is preferably selected in order to maximise fines containment while permitting the necessary water flow rate out of the hood to accommodate slurry inflows into the hood. For example the filter material may comprise a silt curtain of 50 micron grade. The seafloor hood preferably comprises a space frame supporting the filter material, with the walls of the hood being formed by the filter material.

Capture of fines from a slurry inflow into the hood can be advantageous both environmentally in avoiding escape of plumes of the seafloor material, and operationally as such fines may represent 30% or more of the seafloor material desired to be gathered.

The stockpile hood may have angled walls forming a substantially frustoconical shape, the walls being at an angle to approximate the expected rill angle of an ore heap so as to avoid a stockpiled ore heap exerting significant outward pressure on the walls.

Further, the present invention provides a seafloor stockpiling device adaptable in some embodiments to deployment at significant water depths. For example some embodiments may be operable at depths greater than about 400 m, more preferably greater than 1000 m and more preferably greater than 1500 m depth. Nevertheless it is to be appreciated that some embodiments of the present invention may also present a useful seafloor mining option in water as shallow as 100 m or other relatively shallow submerged applications. Accordingly it is to be appreciated that references to the seafloor or seabed are not intended to exclude application of the present invention to mining or excavation of lake floors, estuary floors, fjord floors, sound floors, bay floors, harbour floors or the like, whether in salt, brackish, or fresh water, and such applications are included within the scope of the present specification.

BRIEF DESCRIPTION OF THE DRAWINGS

An example of the invention will now be described with reference to the accompanying drawings, in which:

FIG. 1 is a simplified overview of a subsea system utilising a stockpiling hood in accordance with one embodiment of the present invention;

FIGS. 2a to 2f illustrate the stockpiling hood in accordance with an embodiment of the present invention;

FIG. 3 illustrates gathering from the stockpile;

FIG. 4 illustrates overlaid stockpiles;

FIG. 5 illustrates a cross sectional view of a stockpiling hood with inclined settler panels;

FIG. 6 illustrates a cross sectional view of a stockpiling hood with an offset lifting point;

FIG. 7 illustrates a cross sectional view of a stockpiling hood with a friction reduction mechanism;

FIG. 8a illustrates a cross sectional view of another friction reduction mechanism in a rest position; and

FIG. 8b illustrates a cross sectional view of the friction reduction mechanism illustrated in FIG. 8a in a lifting position.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 is a diagrammatic overview of a subsea system 100 in accordance with one embodiment of the present invention. A derrick 102 and dewatering plant 104 are mounted upon a surface vessel in the form of an oceangoing production support vessel (PSV) 106. PSV 106 has ore transfer facilities to load retrieved ore onto barge 108.

The present embodiment provides a system 100 operable to around 2500 m depth, however alternative embodiments may be designed for operation to 3000 m depth or greater. During production operations, one or more seafloor mining tools (SMTs) 112 are used to excavate seafloor material, preferably ore, from the seabed 110.

Ore mined by the seafloor mining tool 112 is gathered upon being cut and pumped, in the form of slurry, from the seafloor mining tool 112 through a stockpile transfer pipe (STP) 128 to a seafloor stockpiling device 124. The seafloor stockpiling device 124 captures ore from the slurry while permitting egress of water from the slurry.

A gathering tool 114 inserts a boom-mounted suction inlet into the seafloor stockpiling device 124 via a door 220 (see FIG. 2a), to gather ore in slurry form from inside the seafloor stockpiling device 124. The slurry is then transferred to the base of a riser 122 where a subsea lift pump 118 lifts the slurry, via a rigid riser 122, (shown interrupted in FIG. 1, and may be up to 2500 m long in this embodiment) to PSV 106. At
the PSV 106 the slurry is dewatered by plant 104. The waste water is returned under pressure back to the seafloor to provide charge pressure for subsea lift pump 118. The dewatered ore is offloaded onto transport barge 108 to be transported to a stockpile facility before being transported to a processing site.

[0037] FIGS. 2a to 2d illustrate the stockpiling device in the form of a stockpiling hood 124 in more detail. The stockpiling hood 124 comprises transfer pipe connectors 202 and 204, which are subsea hose connectors, to permit multiple seafloor tools 112 to gather ore into the hood stockpiling 124 simultaneously. Slurry flow is directed into the hood by the transfer pipe connectors 202 and 204 generally vertically downwards. Hood 124 further comprises a lifting attachment in the form of lift gear 206 for deployment, relocation and recovery of hood 124.

[0038] The stockpiling hood 124 has walls comprising panels 208 that, together with the seafloor 110, define a cavity for stockpiling seafloor material (as illustrated in FIG. 3).

[0039] The panels 208 are removable and formed of a frame 212 with a water permeable skin in the form of a geotextile covering 214.

[0040] Due to the large geometry of the stockpiling hood 124 there is a large in water added mass associated with the device due to the geotextile covering 214. This added mass causes in water lifting drag to increase dramatically over that of conventional lifts. As a result in this embodiment the geotextile covering 214 is able to be rotated to align with a direction of movement before any lifting operations occur. The panels 208 are able to be opened to reduce water resistance during movement of the stockpiling hood 124. The geotextile covering 214 reduces the outflow velocity to allow settlement of larger spoil particles and retain fines larger than 30-60 microns. In case of differential pressure across the filter material rising due to filter pore blockages, a relief valve or flap is provided to avoid rupture of the filter material.

[0041] As shown in FIG. 2b, the stockpiling hood 124 is formed of two modules 124a and 124b which can be separately deployed from a surface vessel and then brought together on the seafloor. This arrangement permits the stockpiling hood 124 as a whole to exceed the weight limits of a surface vessel’s deployment systems. FIG. 2c is a plan view of the stockpiling hood 124, while FIG. 2d is an elevation view of the stockpiling hood 124.

[0042] During lifting and lowering operations the drag of the hood is substantial. To reduce this it is desirable to allow water to flow through the structure. FIGS. 2e and 2f show opening flaps 210 in the top of the stockpiling hood 124 in the closed and open positions, respectively, the latter reducing drag during hood movement.

[0043] Provision is made in the design of the stockpiling hood 124 for access by the gathering machine 300 via doors in the form of flaps 220, which comprises a rubber panel with suitably arranged slots to permit a gathering portion in the form of a boom mounted suction inlet 302 of the gathering machine 300 to be inserted through flap 220. Flaps 220 are provided at several locations to provide gathering from all sides of the stockpile, and do not require any power to function. The flaps 220 are designed to avoid excessive leakage of slurry when not in use by gathering machine 300.

[0044] This embodiment thus filters the flow of ore slurry being pumped from one or more sea floor production tools. This slurry is a high volume flow and the slurry velocity needs to be reduced to allow the ore to settle out of the flow onto the sea floor. The stockpiling hood 124 reduces the amount of ore lost from such a slurry flow and is designed to minimise the disturbance of the ore pile created when the stockpiling hood 124 is relocated. The stockpiling hood 124 is able to be shifted by an overhead crane on a vessel so as to be re-useable.

[0045] An inflow of ore slurry is slowed inside the stockpiling hood 124 due to the large volume of the stockpiling hood 124, and the large surface area covered in the geotextile covering 214. Larger ore particles in the slurry are fast settling and settle to the stockpile in a slow flow region. A large volume slurry flow moves through the geotextile covering 214 at low velocity with the geotextile covering 214 filtering slow-setting particles from the flow.

[0046] FIG. 3 illustrates a gathering machine 300 gathering ore from a stockpile 500 within the stockpiling hood 124. In FIG. 3 the stockpiling hood 124 is illustrated without the geotextile covering for clarity. With the geotextile covering in place, the gathering portion 302 of the gathering machine 300 is inserted through flaps 220 of the stockpiling hood 124. FIG. 3 also illustrates the size of a full stockpile 502 contained within the stockpiling hood 124.

[0047] FIGS. 4a and 4b illustrate a method to increase standard stockpile 500 size using a hood 124 with a rigid skirt 310. The skirt 310 provides support for ore in the stockpile 500, permitting overfilling of the stockpiling hood 124 which is not possible with non-load bearing hood walls. The method comprises overfilling the stockpiling hood 124 with an overfilled stockpile 504, lifting the stockpiling hood 124 off the overfilled stockpile 504; allowing the overfilled stockpile 504 to collapse into a collapsed stockpile 506, and then placing the stockpiling hood 124 on top of the collapsed stockpile 506.

[0048] FIG. 5 illustrates an embodiment of the stockpiling hood 124 where some of the geotextile covering 214 has been replaced with a filter structure in the form of inclined settlers 216. The inclined settlers 216, which may be either inclined plate or inclined tube settlers, allow water to flow upward out of the stockpiling hood 124 while capturing solids which slide down inclined surfaces of the inclined settlers 216 back into the stockpiling hood 124 to the stockpile 500. The inclined settlers 216 provide a large settling area which increases the settling rate, relative to just using a geotextile covering 214, allowing the settling capacity of the stockpiling hood 124 to be increased and/or the size of the stockpiling hood 124 to be decreased while maintaining the same capacity output. It is envisaged that the walls in their entirety could comprise inclined settlers 216 instead of having geotextile covering 214 portions as illustrated.

[0049] FIG. 6 illustrates a stockpiling hood 124 with an offset lifting attachment in the form of an offset lifting point 218. The offset lifting point 218 is positioned on a side of the stockpiling hood 124 and allows the stockpiling hood 124 to be lifted at an angle by a lifting apparatus 218. By lifting the stockpiling hood 124 at an angle using the offset lifting point 218, static friction, or stick, preventing the stockpiling hood 124 from being lifted is reduced. In this regard, a small amount of peripheral sediment 501 can build up around the perimeter of the stockpiling hood 124 which, together with the stockpile 500, creates stiction between the hood 124 and the seafloor 110.

[0050] By lifting the stockpiling hood 124 from the offset lifting point, the side of the stockpiling hood 124 that is below the offset lifting point 218 is lifted first, reducing the total
break force required to overcome the stiction. Once the stiction has been overcome, the stockpiling hood 124 can then be raised and manoeuvred using a central lift gear 206.

[0051] FIG. 7 illustrates a reduction friction mechanism that also assists in reducing stiction between the stockpiling hood 124 and the seafloor 110. Pipe transfer connectors 202 and 204, which are connected to STPs 128, have diverter valves which can be actuated to divert some of the flow down conduits 222 to fluid outlets in the form of nozzles 224 at the bottom of the stockpiling hood 124. When the diverter valves are actuated, water pumped by the slurry pump system is pumped into the conduits 222 and out of the nozzles 224. This water loosens material around the periphery of the stockpiling hood 124, including peripheral sediment 501, which reduces friction between the stockpiling hood 124 and the seafloor 110. Once the stiction forces are overcome, the stockpiling hood 124 is relatively easily manoeuvred. It is envisaged that instead of water, air or other fluids could be expelled from nozzles 224.

[0052] FIGS. 8a and 8b illustrate a further friction reduction mechanism which may be used instead of, or even in addition to, the above-mentioned friction reduction mechanism illustrated in FIG. 7. The friction reduction mechanism in FIGS. 8a and 8b has movable walls 230 inside the stockpiling hood 124. The movable walls 230 are pivotable relative to the sides of the stockpiling hood 124. As illustrated in FIG. 8a, the stockpile 500 is retained within the movable walls 230 of the stockpiling hood 124. As the stockpiling hood 124 is lifted, as illustrated in FIG. 8b, the movable walls 230 pivot downwards and away from the stockpile 500. This action effectively eliminates stiction forces between the stockpiling hood 124 and the seafloor 110.

[0053] It will be appreciated by persons skilled in the art that numerous variations and/or modifications may be made to the 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 as illustrative and not restrictive.

1. A seafloor stockpiling device that is located on the seafloor in use, the device comprising:
   a slurry inlet for attachment of a slurry transfer pipe and for receiving slurry from a seafloor tool; and
   a hood with an open bottom comprising walls that substantially define a cavity having a stockpiling volume, the walls being configured to capture and contain seafloor material present in the slurry in the device while permitting egress of water present in the slurry from the device.
2. (canceled)
3. The seafloor stockpiling device of claim 1, wherein the walls define the cavity together with a seafloor surface that the seafloor stockpiling device is located on.
4. The seafloor stockpiling device of claim 1, wherein the walls are water permeable.
5. The seafloor stockpiling device of claim 1, wherein at least a portion of the walls comprise a filter material.
6. The seafloor stockpiling device of claim 5, wherein the filter material is reversibly mounted such that reversing the mounting of the filter material causes an inward facing surface of the filter material to become outward facing.
7. The seafloor stockpiling device of claim 5, wherein the filter material is a geotextile.
8. The seafloor stockpiling device of claim 1, wherein at least a portion of the walls comprise a filter structure.
9. The seafloor stockpiling device of claim 8, wherein the filter structure is an inclined plate or tube settler.
10. The seafloor stockpiling device of claim 1, further comprising movable sections that can be moved to between a storage position and a travel position, wherein the drag load during movement of the seafloor stockpiling device is reduced in the travel position.
11. The seafloor stockpiling device of claim 1, further comprising at least one friction reduction mechanism that reduces static friction between the seafloor stockpiling device and the seafloor.
12. The seafloor stockpiling device of claim 11, wherein the friction reduction mechanism comprises one or more fluid outlets adjacent a bottom portion of the seafloor stockpiling device.
13. The seafloor stockpiling device of claim 12, wherein the one or more fluid outlets are fluidly connected via a conduit to a diverter valve in the slurry inlet.
14. The seafloor stockpiling device of claim 12, wherein the one or more fluid outlets are directed generally towards the seafloor.
15. The seafloor stockpiling device of claim 12, wherein the one or more fluid outlets comprise nozzles.
16. The seafloor stockpiling device of claim 11, wherein the friction reduction mechanism comprises movable walls.
17. The seafloor stockpiling device of claim 16, wherein the movable walls are preferentially contained inside the walls of the seafloor stockpiling device and enclose seafloor material contained within the device.
18. The seafloor stockpiling device of claim 16, wherein the movable walls pivot relative to the walls of the seafloor stockpiling device.
19. The seafloor stockpiling device of claim 1, further comprising a lifting attachment.
20. The seafloor stockpiling device of claim 1, further comprising an offset lifting attachment that is offset from a central axis of the seafloor stockpiling device.
21. The seafloor stockpiling device of claim 20, wherein the offset lifting attachment is located adjacent an outer edge of the seafloor stockpiling device.
22. The seafloor stockpiling device of claim 1, wherein the seafloor stockpiling device is formed from at least two modules configured for separate deployment from a surface vessel and for underwater interconnection.
23. The seafloor stockpiling device of claim 1, further comprising a stockpile removal device.
24. The seafloor stockpiling device of claim 23, wherein the stockpile removal device comprises an opening port in at least one of the walls of the seafloor stockpiling device.
25. The seafloor stockpiling device of claim 1, wherein the walls are angled forming a substantially frustoconical shape.
26. The seafloor stockpiling device of claim 1, further comprising a rigid skirt around the periphery of the seafloor stockpiling device.

* * * * *