<table>
<thead>
<tr>
<th><strong>Title</strong></th>
<th>Drilling process monitor</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>
DRILLING PROCESS MONITOR

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ABSTRACT

An apparatus is used with a drilling assembly for drilling a borehole. The drilling assembly has an impact device linked to a drill head. The impact device is powered by a first fluid under a first pressure to impart a percussive force to the drill head. The percussive force is a function of the first pressure. A thruster of the drilling assembly is also linked to the drill head. The thruster is powered by a second fluid under a second pressure to impart a thrust force to the drill head. The thrust force is a function of the second pressure. Additionally, a rotator of the drilling assembly is linked to the drill head. The rotator is powered by a third fluid under a third pressure to impart a torque to the drill head. The torque is a function of the third pressure. The apparatus includes a first pressure sensor communicating with the first fluid to output a first electrical signal that is a function of the first pressure. A second pressure sensor communicates with the second fluid to output a second electrical signal that is a function of the second pressure. A third pressure sensor communicates with the third fluid to output a third electrical signal that is a function of the third pressure. A position sensor outputs a fourth electrical signal that is a function of depth of the drill head relative to a reference location. A device monitors the first, second, third and fourth signals. The device produces respective graph traces of functions of the percussive force, the thrust force, the torque and the depth.
DRILLING PROCESS MONITOR

[0001] This application claims the benefit of U.S. Provisional Application No. 60/234,535, filed Sep. 22, 2000, and incorporates the Provisional Application by reference.

FIELD OF THE INVENTION

[0002] The present invention relates to systems for drilling holes in the ground.

BACKGROUND

[0003] In a drilling operation, a drilling assembly is used to drill a hole in the earth. It is sometimes desirable to monitor the progress of the drilling operation.

SUMMARY OF THE INVENTION

[0004] An apparatus is used with a drilling assembly for drilling a borehole. The drilling assembly has a drill head. An impact device of the drilling assembly is linked to the drill head. The impact device is powered by a fluid under a first pressure to impart a percussive force to the drill head. The percussive force is a function of the first pressure. A thruster of the drilling assembly is also linked to the drill head. The thruster is powered by a second fluid under a second pressure to impart a thrust force to the drill head. The thrust force is a function of the second pressure. Additionally, a rotor of the drilling assembly is linked to the drill head. The rotor is powered by a third fluid under a third pressure to impart a torque to the drill head. The torque is a function of the third pressure. The apparatus includes a first pressure sensor communicating with the first fluid to output a first electrical signal that is a function of the first pressure. A second pressure sensor communicates with the second fluid to output a second electrical signal that is a function of the second pressure. A third pressure sensor communicates with the third fluid to output a third electrical signal that is a function of the third pressure. A position sensor outputs a fourth electrical signal that is a function of depth of the drill head relative to a reference location. A device monitors the first, second, third and fourth signals. The device produces respective graph traces of functions of the percussive force, the thrust force, the torque and the depth.

[0005] In a preferred embodiment, the device produces the graph traces in real time during the drilling operation. The first, second and third electrical signals are analog signals. The fourth electrical signal is a digital signal. The graph traces are indicative of the occurrence of downward drilling, drilling stoppage, raising of the drill head, and addition of drilling rods.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] FIG. 1 is a schematic view of a drilling system according to the present invention; and

[0007] FIGS. 2-9 are graphs produced by the drilling system of FIG. 1.

DESCRIPTION

[0008] An example of a preferred embodiment of the present invention is shown schematically in FIG. 1. The preferred embodiment is a drilling system 10 that includes a drilling assembly 14 and a monitoring system 16. The drilling assembly 14 performs a drilling operation defined by drilling a borehole 20 in the earth 22. The monitoring system 16 measures and displays dynamic parameters related to the drilling operation.

[0009] In this embodiment, the drilling assembly 14 is a pneumatic percussive rotary drilling machine. The drilling assembly 14 has a drill head 24 at the end of a drill string 26 defined by a series of drilling rods. During the drilling operation, the drill head 24 rotates and vibrates while being thrust into the bottom end 28 of the borehole 20.

[0010] The drill head 24 is linked to an impact device 30 in a known manner. The impact device 30 applies a percussive force, indicated by arrow 32, which is transmitted through the drill string 26 to the drill head 24 to fragment soil and drive the drill head 24 into the bottom end 28 of the borehole 20. The impact device 30 is powered by a first fluid 36 under a first pressure. The percussive force at the drill head 24 is a function of the first pressure.

[0011] The drill head 24 is also linked to a thruster 42. The thruster 42 can apply a downward force, indicated by arrow 44, that is transmitted through the drill string 26 to the drill head 24 to thrust the drill head 24 into the earth 22. The thruster 42 can also apply an upward force, indicated by arrow 46, that is transmitted through the drill string 26 to the drill head 24 to raise the drill head 24. The thruster 42 is powered by a second fluid 48 under a second pressure and a third fluid 50 under a third pressure. The downward force is a function of the second pressure. The upward force is a function of the third pressure.

[0012] The drill head 24 is further linked to a rotor 54. The rotor 54 can apply a forward torque, indicated by arrow 56, that is transmitted through the drill string 26 to the drill head 24 to rotate the drill head 24 in a forward direction. Rotation of the drill head 24 in the forward direction causes the drill head 24 to abrade, and to be driven downward through the bottom end 28 of the borehole 20. The rotor 54 can also apply a reverse torque, indicated by arrow 58, that is transmitted through the drill string 26 to the drill head 24. Rotation of the drill head 24 in the reverse direction assists in removing the drill head 24 from the bottom end 28 of the borehole 20. The rotor 54 is powered in the forward direction by a fourth fluid 60 under a fourth pressure. The rotor 54 is powered in the reverse direction by a fifth fluid 62 under a fifth pressure. The forward torque is a function of the fourth pressure. The reverse torque is a function of the fifth pressure.

[0013] In this embodiment, each of the first, second, third, fourth and fifth fluids 36, 48, 50, 60 and 62 is a gas. However, for use with hydraulic drilling assemblies, these fluids would be liquids. These fluids 36, 48, 50, 60 and 62 are compressed from a common fluid supply 64 into a manifold 66 by a compressor 68 and are delivered to the corresponding devices 30, 42 and 54. Delivery of each of these fluids 36, 48, 50, 60 and 62 to the respective device 30, 42 and 54 is controlled by a controller 70.

[0014] The monitoring system 16 includes five individual pressure sensors 71, 72, 73, 74 and 75 for measuring the pressure of the five fluids 36, 48, 50, 60 and 62, respectively. The pressure sensors 71, 72, 73, 74 and 75 are in communication with the respective fluids 36, 48, 50, 60 and 62 through fluid lines 80. The pressure of each fluid 36, 48, 50, 60 and 62 is conducted through the respective fluid line 80.
to the respective pressure sensor 71, 72, 73, 74 and 75. Each
pressure sensor 71, 72, 73, 74 and 75 produces an analog
electrical signal that is a function of the pressure of the
respective fluid 36, 48, 50, 60 and 62. The signals are output
onto respective electrical lines 81, 82, 83, 84 and 85.

[0015] A position sensor 86 is operative to measure the
depth of the drill head 24 relative to a reference location.
The reference location is a fixed location 92 on the surface of
the earth 22. Alternatively, the reference location can be a fixed
location (not shown) on the drilling assembly 14. The depth
measurement may be accomplished in any suitable manner
known in the art. The position sensor 86 produces a digital
signal representing a value that is a function of the depth of
the drill head 24. The digital signal is output on an electrical
line 96.

[0016] The five analog signals and the one digital signal
are communicated over the lines 81, 82, 83, 84, 85 and 96
to a micro-processor controller 98. The micro-process controller
98 converts the five analog signals and the one digital
signal to six corresponding digital data typically in RS232
format. The micro-process controller 98 functions as a data
buffer to manipulate the data and change data format. The
micro-process controller 98 also controls the data collection
of the six electrical signals in real time simultaneously via
the six lines 81, 82, 83, 84, 85 and 96. The micro-process
controller 98 can continuously store the digital data on a disk
drive (not shown) in real time.

[0017] In the present embodiment, the micro-process controller
98 outputs the digital data over an electrical line 99 to a computer 100, which in the present embodiment is a
personal computer. During the drilling operation, the computer
100 continuously stores the digital signals on a disk
drive (not shown) in real time and can continuously produce
graphs of the respective digital signals in real time. Each
graph is displayed on a suitable medium, such as a sheet of
paper.

[0018] FIGS. 2-7 show graphs 102, 103, 104, 105, 106 and
107 corresponding to the first, second, third, fourth, fifth and
sixth digital signals, respectively, for a first typical drilling
operation. FIGS. 8 and 9 show graphs 108 and 109
respective to the first and sixth signals, respectively, for a
second typical drilling operation.

[0019] The graphs 102, 103, 104, 105, 106, 107, 108 and
109 in FIGS. 2-9 have many features in common. These
features can be explained with reference to the graph 102 of
FIG. 2. Graph 102 includes a vertical axis 122 representing
signal magnitude. The vertical axis 122 is graduated in terms
of pressure in units of kPa. A horizontal axis 124 represents
eclipsed time relative to a start time designated as zero. The
horizontal axis 124 is graduated in units of seconds. Graph
102 also includes a trace 126 based on the first digital signal
corresponding to percussive force. The vertical position of
each point along the trace 126 is a function of the first
pressure at the time that point was measured.

[0020] In graph 103 of FIG. 3, the trace 126 is based on
the second digital signal. The trace 126 is thus a function of
the second pressure, corresponding to downward thrust.
Similarly, the trace 126 of the graph 104 of FIG. 4 is based
on the third digital signal and is therefore a function of the
third pressure, corresponding to upward thrust. Likewise,
the trace 126 of the graph 105 of FIG. 5 is based on the
fourth digital signal. It is consequently a function of the
fourth pressure, corresponding to forward torque. The trace
126 of the graph 106 of FIG. 6 is based on the fifth digital
signal. It is thus a function of the fifth pressure, correspond-
ing to reverse torque.

[0021] In graph 107 of FIG. 7, the vertical axis 122 is
graduated in terms of depth in units of meters. This is in
contrast to the graphs 102, 103, 104, 105 and 106 (FIGS.
2-6, respectively) in which the vertical axes 122 are gradu-
ated in terms of pressure. In graph 107 of FIG. 7, the trace
126 is based on the sixth digital signal. The vertical position
of each point along the trace 126 is consequently a function
of depth of the drill head 24 (FIG. 1) at the time that point
was measured.

[0022] The graph 108 of FIG. 8 is similar to the graph 102
of FIG. 2, but is for the second drilling operation. Likewise,
the graph 109 of FIG. 9 is similar to the graph 107 of FIG.
7, but is for the second drilling operation.

[0023] In this embodiment, the traces 126 are plotted on
separate graphs 102, 103, 104, 105, 106, 107, 108 and 109
(FIGS. 2-9), each having a separate horizontal axis 124.
However, the horizontal axes 124 of graphs relating to the
same operation are the same in size and in time scale. For
example, the horizontal axes 124 of the graphs in FIGS. 2-7
all have the same time scale, 0-4000 seconds.

[0024] During and after the drilling operation, an operator
can interpret the graphs shown in FIGS. 2-9 to assess the
progress of the drilling operation, to note any irregularity in
the operation, and to discern the subsurface profile and
properties. The operator can also interpret these graphs to
determine when different operations have been performed.
For example, referring to graph 109 in FIG. 9, section A
corresponds to downward drilling, section B corresponds to
drilling stoppage, section C corresponds to raising of the
drill head 124, and section D corresponds to addition of
drilling rods.

[0025] The invention has been described with reference to
preferred embodiments. Those skilled in the art will perceive
improvements, changes and modifications. Such improve-
ments, changes and modifications are intended to be within
the scope of the claims.

1. Any in-situ devices or instruments to automatically and
continuously measure and record the drilling process while
drilling holes in ground using pneumatic percussive rotary
drilling machines, comprising:

a distance sensor device to measure the downward,
upward or stoppage movement of the drill chuck or
head in vertical, horizontal or inclined directions with
respect to fixed points on the ground or the drilling
machines;

air pressure transducers to measure the compressed air
pressures from the drilling machine controller applied
to the drilling rig; and

a micro-process controller and a personal computer to
convert, transfer and store the distance and pressure
measurements in digital format.

2. Any in-situ devices or instruments to automatically and
continuously measure and record the drilling process while
drilling holes in ground using hydraulic percussive rotary
drilling machines, comprising:
a distance sensor device to measure the downward, upward or stoppage movement of the drill chuck or head in vertical, horizontal or inclined directions with respect to fixed points on the ground or the drilling machines;

fluid pressure transducers to measure the compressed fluid pressures from the drilling machine controller applied to the drilling rig; and

a micro-process controller and a personal computer to convert, transfer and store the distance and pressure measurements in digital format.

3. Any in-situ devices or instruments to automatically and continuously measure and record the drilling or boring process while drilling holes in ground using hydraulic rotary drilling machines, comprising:

a distance sensor device to measure the downward, upward or stoppage movement of the drill chuck (or head) in vertical, horizontal or inclined directions with respect to fixed points on the ground or the drilling machines;

fluid pressure transducers to measure the compressed fluid pressures from the drilling machine controller applied to the drilling rig; and

a micro-process controller and a personal computer to convert, transfer and store the distance and pressure measurements in digital format.

4. An apparatus for use with a drilling assembly for drilling a borehole, the drilling assembly having:

a drill head;

an impact device linked to the drill head, the impact device being powered by a first fluid under a first pressure to impart a percussive force to the drill head, the percussive force being a function of the first pressure;

a thruster linked to the drill head, the thruster being powered by a second fluid under a second pressure to impart a thrust force to the drill head, the thrust force being a function of the second pressure; and

a rotator linked to the drill head, the rotator being powered by a third fluid under a third pressure to impart a torque to the drill head, the torque being a function of the third pressure;

said apparatus comprising:

a first pressure sensor communicating with the first fluid to output a first electrical signal that is a function of the first pressure;

a second pressure sensor communicating with the second fluid to output a second electrical signal that is a function of the second pressure;

a third pressure sensor communicating with the third fluid to output a third electrical signal that is a function of the third pressure;

a position sensor that outputs a fourth electrical signal that is a function of depth of the drill head relative to a reference location; and

a device that monitors said first, second, third and fourth signals, and that produces respective graph traces of functions of the percussive force, the thrust force, the torque and the depth.

5. The apparatus of claim 4 wherein said device produces said graph traces in real time during the drilling operation.

6. The apparatus of claim 4 wherein said first, second and third electrical signals are analog signals.

7. The apparatus of claim 4 wherein said fourth electrical signal is a digital signal.

8. The apparatus of claim 4 wherein said graph traces are indicative of the occurrences of downward drilling, drilling stoppage, raising of the drill head, and addition of drilling rods.