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(54) Title: METHOD AND APPARATUS FOR COLLECTING DRILL BIT PERFORMANCE DATA

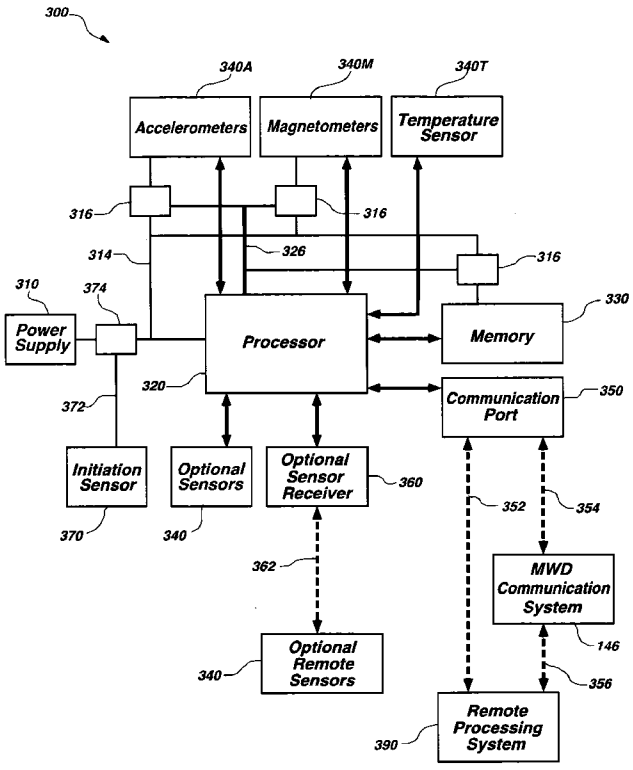


FIG. 6

(57) Abstract: Drill bits and methods for sampling sensor data associated with the state of a drill bit are disclosed. A drill bit (200) for drilling a subterranean formation comprises a bit body (240) and a shank (210). The shank further includes a central bore (280) formed through an inside diameter of the shank and configured for receiving a data analysis module (290). The data analysis module comprises a plurality of sensors, a memory, and a processor (300). The processor is configured for executing computer instructions to collect the sensor data by sampling the plurality of sensors, analyze the sensor data to develop a severity index, compare the sensor data to at least one adaptive threshold, and modify a data sampling mode responsive to the comparison. A method comprises collecting sensor data by sampling a plurality of physical parameters associated with a drill bit state while in various sampling modes and transitioning between those sampling modes.

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Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:

— *with international search report*

— *with amended claims and statement*

— *with information concerning one or more priority claims considered void*

Date of publication of the amended claims and statement:
23 October 2008

AMENDED CLAIMS
received by the International Bureau on 02 September 2008 (02.09.09)

What is claimed is:

1. A drill bit for drilling a subterranean formation, comprising:
a bit body bearing at least one cutting element;
a shank including a central bore formed therethrough, the shank secured to the bit body and adapted for coupling to a drillstring;
an end-cap configured for disposition in the central bore and forming an annular chamber in the shank between the central bore and a sidewall of the end-cap;
at least one sensor disposed in the drill bit and configured for developing sensor data by sensing at least one physical parameter; and
a data analysis module disposed in the annular chamber and comprising:
a memory; and
a processor operably coupled to the memory and the at least one sensor, the processor configured for executing computer instructions, wherein the computer instructions are configured for:
collecting the sensor data by sampling the at least one sensor; and
determining at least one state of the drill bit responsive to the sensor data.

2. The drill bit of claim 1, wherein the at least one sensor comprises a pressure activated switch, comprising:
a fixed member disposed in a recess of the bit body and configured to be held in a fixed position during a change in a pressure substantially near the bit body;
a displacement member disposed in the recess and configured to be displaced within the recess in response to the change in the pressure substantially near the bit body; and
a deformable member disposed between the fixed member and the displacement member and configured to deform in response to the change in the pressure substantially near the bit body such that the displacement member is displaced relative to the fixed member;

AMENDED SHEET (ARTICLE 19)

wherein the pressure activated switch is configured to generate a pressure signal responsive to the change in the pressure.

3. The drill bit of claim 2, wherein the deformable member comprises a device selected from the group consisting of a piezoelectric device configured to modify the pressure signal responsive to the change in the pressure and an O-ring with a durometer selected for a predetermined deformation at a predetermined pressure.

4. The drill bit of claim 2, wherein the pressure activated switch is configured for maintaining a high-pressure seal and a watertight seal to protect at elements of the pressure activated switch and the data analysis module.

5. The drill bit of claim 1 or 2, wherein the at least one sensor comprises a load cell affixed in a load cell chamber within the bit body wherein the load cell chamber is in communication with the chamber, the load cell comprising:

a first attachment section configured for attachment to the load cell chamber;

a second attachment section configured for attachment to the load cell chamber;

a stress section disposed between the first attachment section and the second attachment section and configured with at least one surface for receiving at least one strain gauge;

at least one strain gauge affixed to the at least one surface; and

conductors operably coupled to the strain gauge and configured to pass through the load cell chamber and into the chamber.

6. The drill bit of claim 5, wherein the at least one strain gauge is configured for sensing at least one drill bit parameter selected from the group consisting of stress on the bit, weight on bit, longitudinal stress on the bit, longitudinal strain exhibited by the bit, torsional stress on the bit, and torsional strain exhibited by the bit.

7. The drill bit of claim 1 or 2, further comprising:

a power supply coupled to the data analysis module; and

a power gating module coupled to the power supply and the at least one sensor;

wherein the power gating module is configured for operably coupling the power supply to the data analysis module when the at least one state reaches a predetermined threshold.

8. The drill bit of claim 7, wherein:

the at least one sensor is selected from the group consisting of a temperature sensor configured for sensing a temperature of the drill bit and a pressure activated switch; and

the at least one state is selected from the group consisting of a predetermined temperature and a predetermined pressure.

9. The drill bit of claim 1 or 2, wherein the determining at least one state of the drill bit comprises determining a remaining battery life estimate responsive to computer instructions configured for determining a battery parameter selected from the group consisting of a voltage from the battery, a current from the battery, a history of sampled voltages, a history of sampled currents, and combinations thereof.

10. The drill bit of claim 1 or 2, further comprising computer instructions configured for adjusting behavior of the data analysis module responsive to the at least one state by performing at least one process selected from the group consisting of reducing sampling frequency of the at least one sensor, removing power from the at least one sensor, ensuring a voltage to the at least one sensor is adequate to sample properly, ensuring adequate voltage exists to store data to the memory.

11. The drill bit of claim 1 or 2, wherein:

the at least one sensor comprises at least two sets of accelerometers disposed at different locations within the drill bit, each accelerometer set configured for sensing an acceleration along at least one axis; and

the computer instructions are further configured for:

collecting the sensor data by sampling the at least two sets of accelerometers at a series of sample times; and

determining an acceleration of the drill bit in at least one direction responsive to the collected sensor data.

12. The drill bit of claim 11, wherein the computer instructions are further configured for performing an integration of the sensor data to determine a velocity profile in the at least one direction.

13. The drill bit of claim 12, wherein the computer instructions are further configured for performing an integration of the velocity profile to determine a bit trajectory in the at least one direction.

14. The drill bit of claim 1 or 2, wherein the computer instructions are further configured for analyzing information derived from the sensor data to develop a time encoded parameter stream of the information, wherein the analyzing comprises:
partitioning the information into epochs, each epoch comprising consecutive samples between zero crossings;
determining a duration parameter as a number of samples for each epoch; and
determining a shape parameter as a number of minima or a number of maxima for each epoch.

15. The drill bit of claim 14, further comprising computer instructions configured for converting the time encoded parameter stream to a symbol stream wherein each symbol in the symbol stream is based on a predetermined alphabet of symbols developed as a combination of possible duration parameters and possible shape parameters.

16. A method, comprising:

collecting sensor data at a sampling frequency by sampling at least one sensor disposed in a drill bit, wherein the at least one sensor is responsive to at least one physical parameter associated with a drill bit state; and

analyzing the sensor data in the drill bit to develop a time encoded parameter stream of the sensor data, wherein the analyzing comprises:

partitioning the sensor data into epochs, each epoch comprising consecutive samples between zero crossings;

determining a duration parameter as a number of samples for each epoch; and

determining a shape parameter as a number of minima or a number of maxima for each epoch.

17. The method of claim 16, further comprising determining an amplitude parameter as the largest absolute value sample for each epoch.

18. The method of according to claim 16 or 17, further comprising converting the time encoded parameter stream to a symbol stream wherein each symbol in the symbol stream is based on a predetermined alphabet of symbols developed as a combination of possible duration parameters and possible shape parameters.

19. The method of claim 18, further comprising:

converting the symbol stream to a histogram, each element of the histogram representing one of the alphabet symbols and comprising a number of symbols in the symbol stream matching that element symbol; and

analyzing the histogram with a trained neural network to determine if the histogram represents a drill bit behavior of interest.

20. The method of claim 19, further comprising:

developing a severity index from analyzing the histogram;

comparing the severity index to at least one adaptive threshold; and

modifying a data sampling mode responsive to the comparison.

STATEMENT UNDER ARTICLE 19 (1)

September 2, 2008

VIA FACSIMILE TRANSMISSION
CONFIRMATION VIA FEDERAL EXPRESS

International Bureau of WIPO
34 chemin des Colombettes
1211 Geneva 20
SWITZERLAND

ATTENTION: Henrik Strømmen, Authorized Officer

Re: PCT INTERNATIONAL PATENT APPLICATION

Invention	METHOD AND APPARATUS FOR COLLECTING DRILL BIT PERFORMANCE DATA
Inventors	Pastucek *et al.*
Applicant	Baker Hughes Incorporated
Application No.	PCT/US2008/002078
Filing Date	15 February 2008
Agent's File Ref.	48439940WOCP

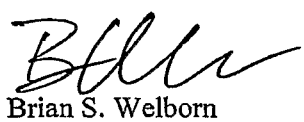
STATEMENT UNDER ARTICLE 19(1) (RULE 46.4)

Dear Examiner Strømmen:

Applicant has amended claim 1. The amendment has no impact on the description and the drawings.

The amendments to claim 1 recite, among other things, that the end-cap is configured for disposition in the central bore and forms an annular chamber in the shank between the central bore and a sidewall of the end-cap.

Very truly yours,



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