COLIBRYS
SMART SENSING SOLUTIONS

APPLICATION NOTE

Down borehole & directional drilling

30N.DRILLING.D.05.11

Features

- ±1g and ±2g range (larger g range also available)
- Harsh environment
- Best long term stability
- Low temperature coefficient without calibration
- Low power
- Small size and low weight
- RoHS compliant suitable for lead free soldering process and SMD mounting

The MS9002 for harsh environment drilling application

Introduction

The Energy market in general and the Oil and Gaz market in particular use an extensive array of sensors covering a wide range of functions and applications. Amongst this panoply of sensors the 'accelerometer' is one of the most widely used, operating in various different configurations from measuring pure acceleration (inertia), to vibration, low frequency seismic signals, angular tilt and shocks.

Numerous applications have already taken advantage of this new sensor technology contributing greatly to the increasing adoption of MEMS in the Energy market. Some examples of applications include:

- Precision tilt measurement in Down borehole "measurement whilst drilling" (MWD) and logging (survey on connection)
- Guidance and localization in absence of GPS signals such as in mines, underwater Remote Observation vehicles (ROVs), or whilst drilling.
- Shallow and deep subsurface geoseismic imaging and reservoir monitoring
- Downbore hole and cross borehole seismic measurement
- Structure integrity monitoring (oil rigs, dams, wind turbines, nuclear plants…)
- Inertial measurement within pipeline monitoring PIGs
- Platform stabilization, tilt measurements
- Preventive industrial maintenance through vibration measurements

Underground drilling is a well established and recognized process involving high technologies in harsh vibration, temperature and corrosive environments. This technology has been developed to be used in a variety of applications for various markets. Drilling can vary greatly dependent on the location (land or sea) and soil structures involved. Whether for prospecting, surveillance or exploration, there are different techniques to produce either rock chips or core samples.

Drilling for mining

The main objective of this technique is to sample the subsurface down to a depth of ~500m (~1650 feet) to understand precisely the constitution of the soil for potential future extraction. Drilling in mining is also extensively used to release gases from coal seams. The cost induced by the drilling approach can represent almost half of the total mining exploitation costs due to the large number (few hundreds) of exploratory holes required.

In such applications, tilt sensors are used to determine precisely the orientation and depth of drilled holes, thereby generating a precise maping of the area. It is also used to monitor the stabiloty of the area through monitoring of the potential deformation of existing holes.

Drilling for oil & gas

Various oil & gas applications related to drilling use accelerometers:
- Standard static holes survey with the objective of qualifying and mapping existing holes after drilling or over time.
- Dynamic directional drilling to reach large underground areas from a local platform (eg. Ocean or land platform)
- To expose more of the reservoir to the well bore (eg. Horizontal drilling), Measurement While Drilling (MWD) is performed under harsh environments and is required to guide the drilling head to the targeted location. Rugged, high precision and high temperature sensors are required for these measurements.
- Down borehole seismic and cross bore hole imaging techniques realize much higher local resolution thanks to digital MEMS seismic sensors.

This means that precise localization of resources down to below >5000m (>16'500 feet) is now feasible despite requiring precise directional drilling to hit the expected reservoir location.

Maladière 83 | 2000 Neuchâtel | Switzerland
P +41 32 720 58 11 | F +41 32 720 57 84
www.colibrys.com

APPLICATION NOTE

Horizontal directional drilling (HDD)

Similar techniques are used for surface directional drilling to accurately drill holes under large structures such as rivers or wide roads, for tunneling or to install infrastructure (water pipes, telecommunications or power cables, gas lines) in urban areas. High stability tilt sensors are required to ensure the required accuracy.

Down borehole survey

Boreholes surveying is used for a variety of objectives. Seismic survey for reservoir monitoring and geophysical applications (earthquake monitoring) using tilt sensors that can assess underground stability over a period of time.

Various grades and types of accelerometers (seismic, vibration, shock and tilt) are required for accurate measurements and their effectiveness in harsh environments (vibration, extreme temperatures and shocks) is critical.

This is where MEMS technology takes the lead.

Drilling technologies

More than 50% of new wells use one of the two following methods:
- Mud motor based steerable drilling systems
- Rotary steerable drilling systems

Fig. 1: Rotary steerable drilling system.

For the other 50%, various other drilling techniques are used depending on soil configuration and constitution along with breadth and depth of the holes.

Typical other techniques include:

- ‘No rotation’ - includes direct push rigs
- ‘Rotary table’ achieved by turning a square or hexagonal pipe at drill floor level.
- ‘Top-drive’ where rotation and circulation is done at the top of the drill string
- ‘Sonic’ using primarily vibratory energy to advance the drill string
- ‘Hammer’ using rotation and percussive force
- ‘Rotary air blast drilling’ (RAB)

Sensor instruments

Considering the various drilling applications and measurement requirements, three main accelerometer configurations are extensively used:

Inertial guidance: The objective is to actively guide the drilling head to its final location. The theory is the same as the guidance of a flying object using an IMU combining three gyros and three accelerometers to continuously track the position whilst drilling. Considering the aggressive environment, such measurements are performed under harsh vibrations and shocks. Therefore, the sensors have to be highly insensitive to such perturbations (Vibration Rectification Error (VRE) or post shock bias stability) to provide as accurate measurements as possible.

Tilt for logging: Depending on the expected precision and strength of the surrounding magnetic fields, two methods are possible to determine Azimuth and Tilt at any point down the hole
1) The simplest consists of a tri-axial magnetometer and tri-axial accelerometer to determine the instrument orientation
2) A more complex solution will integrate a tri-axial gyroscope module in addition to magnetometers and accelerometers to monitor the rotation over a period of time.

With either approach, the increased stability of the sensors helps reducing the number of measurement points required to give precise results, therefore reducing the survey cost.

Standard static holes survey are performed with the objective of qualifying and mapping existing holes after drilling or over time.

APPLICATION NOTE

Seismic: In some specific cases, precise seismic measurements can be performed underground to be protected from any human interference and to improve the sensitivity of the measurements. This method is used for cross borehole, seismic whilst drilling, reservoir monitoring during oil & gas extraction or for earthquake monitoring. Very low noise sensors at the level of geophones specification are required to perform such fine measurements.

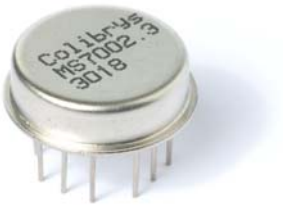
Down borehole seismic and cross bore hole imaging techniques realize much higher local resolution thanks to digital MEMS seismic sensors. This means that precise localization of resources down to more than 5000m (16'500 feet) is now feasible

Colibrys accelerometers for drilling

Colibrys offers a full breath of inertial, tilt, vibration and seismic accelerometers and fulfils a large range of the drilling sensor requirements. MS9000 and VS9000 products can be used as inertial sensors for guidance, for vibration or for tilt measurements. Available in various g ranges (from ±1g to ±200g), they offer ideal specifications for down borehole and drilling applications.

- **Harsh environment:** MS9000 and VS9000 present a standard shock resistance up to 6000g with minimum impact on specifications. They are also relatively unaffected by major external vibrations. A high shock version capable of taking impacts up to 20'000g has been developed in both HS8000 and HS9000 configurations.
- **Wide temperature range:** All our standard products are tested to withstand a temperature range between -55°C and +125°C. Without formal qualification from Colibrys, our products have been successfully used to temperatures in excess of 140°C to 150°C.
- **High stability:** The RS9000 product, currently under development, will achieve extremely good long term stability, nominally down to 100ppm or better even under harsh environments and will offer vibration rectification coefficients down to 150µg/g2.

For those who have worked with MS7000 products, it remains available and complements the new upgraded MS9000 and VS9000 families. These new product families are available in a LCC20 ceramic packaging and fulfill the same expectations as the MS7000. Their small size ensures flexibility in new product design and now comes with a inbuilt temperature sensor.
Our very low noise SiFlex™ seismic sensors SF1500 and SF2006 are ideal companions to these products.



Principle of operation

MS7000, MS8000, MS9000 and VS9000 sensors are available in ranges from ±1g to ±200g, operating from a single power supply voltage (between 2.5V and 5.5V) with low current consumption (<0.5mA at 5V). Their ratiometric analog voltage output variy between 0.5V and 4.5V for the full-scale acceleration range at a voltage supply of 5V. It is essential to have a stable power supply since any instability is directly transferred to the output. The sensors are fully self-contained and packaged in TO8 or LCC standard ceramic housing, insuring full hermeticity over extended life times. Thy operate over the temperature range of -55°C to +125°C and can survive shocks up to 6'000g. For further technical information please refer to the related product files and specifications.

Conclusion

MEMS accelerometers penetrate more and more high-end applications in the Energy market replacing the well established, expensive and fragile electromechanical devices. The driving forces for this revolution are the need for devices offering the same or even better performance, at lower cost, lower power, smaller size but remaining significantly more robust. The success of high-end MEMS accelerometers is completed by their unique capability to serve harsh environment applications characterized by extreme temperature, vibrations or shock conditions in the Energy markets but also Mil-Aerospace, Industrial and Instrumentation markets.

Colibrys is offering the 'cutting edge' MEMS seismic, inertial, vibration and tilt accelerometers for down borehole, directional drilling and associated applications and is continuously working on new products and new solutions including improved stabilities, higher temperature operation, increased immunity to shocks and vibration or lower noise floor.