MEMS Capacitive Accelerometers

Application Notes

Down borehole & directional drilling

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Features	Applications
Harsh environment	**Drilling survey**
Best long term stability	**Directional drilling**
High temperature	**Surface drilling**
Small size	**MWD**
Low weight	

Introduction

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.

Fig. 1: Offshore platform

Drilling for mining

The main objective is to sample the subsurface down to a depth of 500m (1650 feet) to understand precisely the constitution of the soil for future extraction. Drilling is also extensively used to release gases from coal seams.

Drilling costs can represent almost half of the total mining exploitation costs due to the large number (few hundreds) of exploratory holes required.

In such applications, sensors are used to determine precisely the orientation and depth of holes drilled, thereby generating a precise map of the area.

Drilling for oil & gas

Various oil & gas applications 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 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.

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 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 sensors (seismic, vibration or tilt) are required for accurate results 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 the following methods:

- Mud motor based steerable drilling systems
- Rotary steerable drilling systems

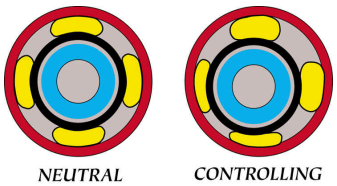

Fig. 2: Rotary steerable drilling system.

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 needed.

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.

Tilt during Survey:
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.

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.

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.
RS9000, MS9000 and VS9000 products can be used as inertial sensors for guidance, for vibration or for tilt measurements. Available in various g ranges 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.

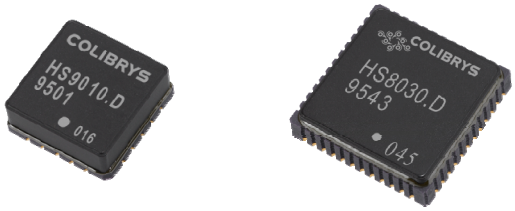

Fig. 3: HS9000 and HS8000 Colibrys accelerometers

A high shock version capable of taking impacts up to 20'000g has been developed in both HS8000 and HS9000 configuration.

- **Wide temperature range:** All our standard products are tested to withstand a temperature range between -55°C and +125°C. Without official testing, our products have been successfully used to temperatures in excess of 150°C.
- **High stability:** The RS9000 product achieves extremely good long term stability, nominally down to 100ppm or better even under harsh environments and offers vibration rectification coefficients down to 150µg/g^2.

This product is one of the first MEMS open loop accelerometer able to compete with QAT160 / T185 from Honeywell for applications where high stability under harsh environment and temperature up to 125°C are required.

Fig. 4: Drilling equipment.

For those who have worked with MS7000 products, this has now been upgraded to the MS / VS9000. These new product families are available in a LCC20 ceramic packaging and fulfill the same expectations as the MS7000. The smaller of the MS / VS9000 ensures flexibility in new product design and now comes with a inbuilt temperature sensor.

Our very low noise SiFlex™ seismic sensors SF1500 and SF2005 are ideal companions to these products.

Principle of operation

MS8000, MS9000 and RS9000 sensors are available in ranges from ±2g to ±200g, operating from a single power supply voltage (between 2.5V and 5.5V) with low current consumption (<0.5mA at 5V). The ratiometric analog voltage output varies 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 sensor is fully self-contained and packaged in a LCC standard ceramic housing, insuring full hermeticity over extended life times. It operates 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 specification and product descriptions.

Conclusion

Colibrys is offering the 'cutting edge' MEMS seismic, inertial, vibration and tilt accelerometers for down borehole, directional drilling and associated applications.
Colibrys 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.

Colibrys (Switzerland) Ltd
accelero.europe@colibrys.com

Colibrys, Inc.
accelero.us@colibrys.com

www.colibrys.com