TFMT19 Sensor Report

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1 Background

This report will describe a completely fictive metal sensor. The sensor system will neither be constructed, nor its sensor mechanisms verified. The system will however be based on real sensor solutions and it is not implausible that it would work in reality. The metal sensor will be designed as a simple, easy to use, tool for miners to quickly monitor rock walls for a wanted metal ore.

2 System description

This section will in detail describe the structure and functionality of the sensor system.

2.1 Overview

The sensor system resembles an ordinary drill. There is the main drill body and the drill bit attachments. In the system, the drill bits will contain the actual sensor and the drill body will be where the data processing and visualization takes place. The idea is that the drill bits are sensitive to a single metal, and that they easily can be swapped out depending on the metal of interest. In Figure 1 an overview of the system is presented.

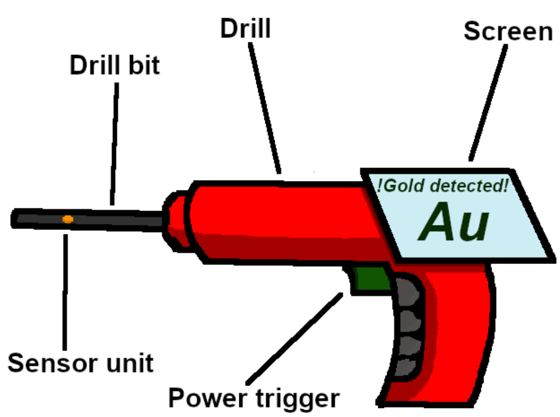

Figure 1: An overview of the sensor system

2.2 Function

The system works as following. First a drill bit is selected based on what metal is of interest. The drill bit is then mounted on the drill and the system is ready to use. A miner can then easily carry the drill to an interesting rock and start drilling. When the drill bit is completely inside the rock, the drill is kept in place until the system has finished analyzing. The sensor analyzes the dust ripped into the air during drilling. Finally the result is displayed on the drill-screen, if the sought after metal was detected or not. Figure 2 shows the system in action.

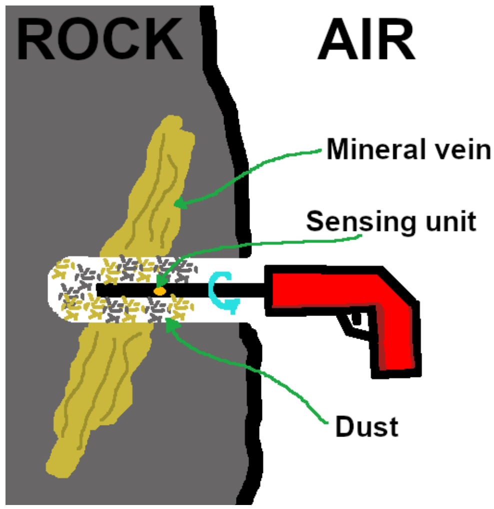

Figure 2: A cross section of the rock during drilling

2.3 The sensor

The sensor is integrated in the drill bit as shown in Figure 3. The unit is covered by a fine metal mesh to stop large particles from damaging the sensor.

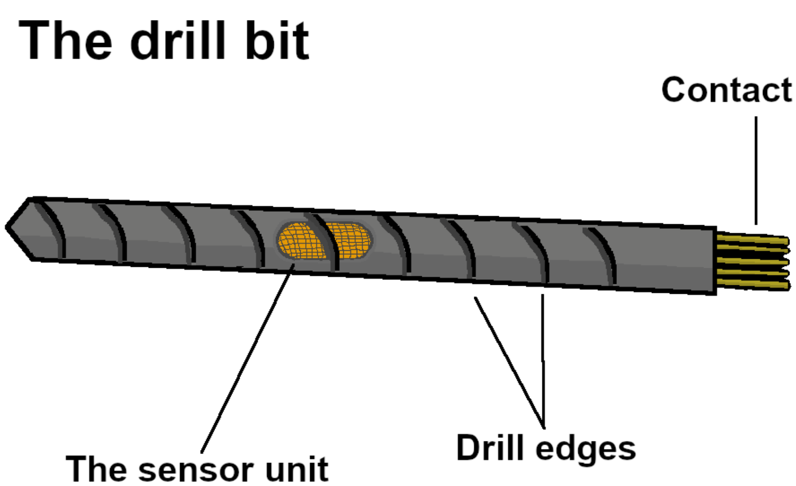

Figure 3: An overview of the drill bit

The sensor unit works by using piezoelectricity and certain peptide combinations which are selective to a specific metal. A piezoelectric crystal generates electrical charge from its mechanical vibrations. The core of the sensor is a piezoelectric crystal, e.g. a quartz crystal. On this crystal many peptide chains are bound. These chains of peptides will bind to the metal particles in the dust that arise from drilling. Binding to the metal will increase the total weight of the sensor which affects the frequency of the crystal oscillations. How the frequency changes due to change in weight can be explained by the Sauerbrey equation

$$\Delta f = -\frac{2f_0^2}{A\sqrt{\rho\mu}}\Delta m \tag{1}$$

where:

f_0 - Resonant frequency of the fundamental mode (Hz)
Δf - Normalized frequency change (Hz)
Δm - Mass change (g)
A - Piezoelectrically active crystal area (cm^2)
ρ - Density of the crystal ($\mathrm{g/cm}^3$)
μ - Shear modulus of crystal for AT-cut crystal ($\mathrm{g} \cdot \mathrm{cm}^{-1} \cdot \mathrm{s}^{-2}$) (Wikipedia, 2020).

So the more metal that binds to the peptides on the crystal, the slower the crystal will oscillate. This means that the analog signal from the sensor will get weaker and weaker the more it binds.

2.3.1 Requirements

Selectivity
The selectivity of this sensor is its most important trait. We assume that we don't know what minerals are in the rock. The dust from the drilling could, and probably does, contain many different elements. Since we are only interested in a single metal it is very important that the sensor does not respond to other elements than that specific metal. In case it would wrongly detect a sought after metal it could bring large costs to the miners if they move expensive equipment only to find that the sensor actually responded to, for example, carbon instead of gold.

Sensitivity
Sensitivity is not that important in this system. The reason being that the system's job is to find larger deposits of metals. If the drill happens to come across a large mineral vein there will probably be a lot of mineral in the dust. Therefore the sensor will probably give a good response anyway. The system only displaying "metal found" or "no metal" is also a reason why sensitivity is not that important.

Speed
Speed is important for this system. First of all the sensor only has until the dust settles to give a proper response, which puts a demand on speed. Secondly, speed from the surveyor's point of view is very nice and could be the deciding factor in what surveying tool to use.

Stability
The stability of the system is not critical, but having good stability is worth striving for. The drill bits are meant to be disposed of when no longer functional. It is however nice to not need to swap drill bit after each drilling. Regular drill bits are often worn out after some uses. A goal would be to make the sensor stable enough so that the drill bit is worn out before the sensor. That would be good from an environmental stand point.

2.4 Electronics

The electronics in the system are split into the drill bit and the drill. The drill bit contains the sensor as well as a microcontroller. The sensor will generate an analog signal which will be converted to digital by an A/D-converter on the microcontroller. The microcontroller will process the signal and send it of via some interface to the drill body. The microcontroller in the drill bit also contains information about that specific drill bit. For example what metal it responds to.

In the drill body there is also a microcontroller. This one is more sophisticated than the one in the drill bit and acts as the brain of the sensor system. It is also connected to a screen which it sends its processed data to. The interface between the two microcontrollers could be an I^2C-bus, SPI-bus, or any equivalent protocol.

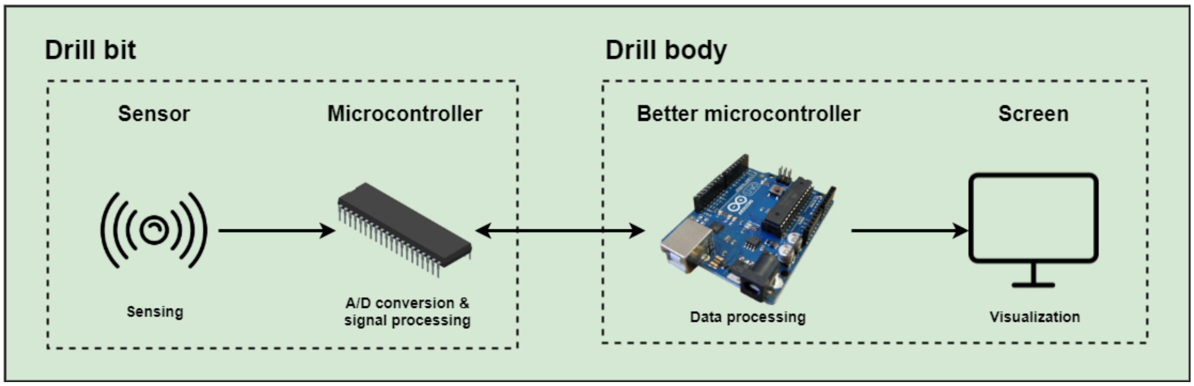

Figure 4: A flowchart of the electronic components in the sensor system

The drill bits are rotating fast in relation to the drill, this makes the electrical contact between the two a bit tricky. You can not use a regular contact since the wires would instantly get tangled up and break. To solve this problem the contact will be a slip ring.

3 Comparison

The sensor mechanism described in this report was inspired by the one used in FREEDD for detection of heavy metals in water. The difference in this case being that we are not interested in the concentration of metal in a sample. Rather we are interested if there is any substantial amount of the metal in the air at all. The drill is also not selective to heavy metals which means that the peptide chains used will be different. The fact that the sample for this application is in air as opposed to water, like the FREEDD, makes the calculation of the frequency change a bit different. A viscosity related decrease in the frequency has to be added for the FREEDD but not for the drill.

References

Wikipedia. Sauerbrey equation. `https://en.wikipedia.org/wiki/Sauerbrey_equation`, 2020. [Online; accessed 2020-05-21].