Engineering Design and Assistance for Astrogeology Research

Michael D. Wilburn
Los Angeles City College
Los Angeles, CA

Mentors- Dr. Rohit Bhartia, Dr. Greg Wanger, Dr. Bill Abbey
Jet Propulsion Laboratory-NASA
Internship-Summer 2014

Abstract

This project focused on designing a custom flow cell, to be used at the Sanford Underground Research Facility (SURF) in South Dakota and designing and building drill mounts to hold rock core samples. The research done at SURF is tasked with describing the nature of microbial life in the deep subsurface and showing the spatial distribution of microbes in the rocks along with the minerals and other organic constituents. Visualizing the distribution of organics and minerals is a major component of Mars 2020 “SHERLOC” instrument and the extremely low biomass of the SURF mine is an excellent test bed for upcoming prototypes. The rock cores will be cryogenically drilled and the powder collected for later DNA extraction. Specific requirements and dimensions were used in the construction of the flow cell using Solidworks®. The flow cells house up to three mineral samples, which serve as the substrate for microbial biofilms. These biofilms can be viewed in situ using a light microscope through windows located on the top of the flow cells. The design of the custom flow cell provided an inexpensive alternative to ordering commercial parts and catered to the specific needs of the experiment. The final design of the flow cell was approved and the project is currently awaiting manufacture by selective laser sintering (SLS) 3D printing.

1 Introduction

The custom design and manufacture of the flow cells, and drills mounts, using 3D printing, are instrumental to current and future research being done at the Sanford Underground Research Facility (SURF) and NASA’s Jet Propulsion Laboratory (JPL). By designing these parts as an alternative to ordering commercially, we were able to save time, money and resources, as opposed to prolonging current and future research.

The design of the flow cell was based off previous experiments at SURF, in which water containing microbial life interacted with test tubes that housed various mineral samples. The custom flow cells were designed to house three mineral samples, which could be viewed in situ using a light microscope through windows located at the top of the flow cell. The design restricts outside contamination by inclosing these biofilms while allowing further observations.

The design of the drill mounts provided an inexpensive, durable, and
reusable tool for DNA extraction from core sample collected from SURF. The drill mounts were designed to hold core samples that were cryogenically frozen as to preserve the contents during extraction.

2 Methods

The designs of the flow cells and drill mounts were both developed using SolidWorks®, a computer-aided design software.

2.10 Flow Cell

The design of the flow cell had to meet certain requirements, which included:

- Manufactured with low cost material, able to hold water for periods up to several months.
- Watertight seals to prevent outside contamination.
- Ports for inflow and outflow of fluid.
- Standard lure fittings at inflow and outflow locations.
- Able to house up to three different mineral samples of varying sizes.
- Viewing windows to hold 20mm by 20mm quartz coverslips, for each mineral sample. (Additional dimension specifications for viewing windows).
- Distance from coverslip to mineral sample not to exceed 2.3mm.

Using these requirements along with commercial flow cells as references, multiple drafts were created until the desired shape of the flow was achieved. The flow cell consisted of three parts; the body, the middle lid, and the top lid.

Once the desired shape was achieved, the design was modified to eliminate material, by thinning the walls, chamfering and/or filleting counters, and changing dimensions to ensure the lowest cost.

The design was then modified to fit the dimension of the PEMs, SEMs, and screws to be used with the flow cell.

- **SEMs**-Ø12.7mm x 15mm pin height. AMRAY 1000/1200/1400, aluminum
- **PEMs**-18-8 Stainless Steel Broach Style Captive Nut 2-56 Thread Size, .060" Minimum Panel Thickness
- **Screws**- #2-56 x 3/8" 100 degree Flat Head Phillips Machine Screw 18-8 Stainless Steel.
2.11 Trouble Shooting

To maximize the viewing ability of the light microscope while staying within the allowable focus distance (2.3mm) the interior walls of the viewing windows on the top lid were chamfered to match the angle (17.09°) of the Olympus 60x lens.

To ensure that the flow cell remained air free, the outflow port was raised above the level of the coverslips. This change allowed any air bubbles that may have entered the flow cell, a means to escape.

2.20 Drill Mounts

The design of the drill mount was based off a pre-existing drill setup involving a heavy-duty drill press, rotated 90° (parallel with the floor), attached to aluminum 80/20, 3”x3” T-slotted framing to ensure maximum support.

The design consisted of two parts connected by four 3”-#18 machined screws with nuts to clamp the core sample down to the aluminum frame. The drill mount was bolted to the aluminum frame using three 1-1/4”-#18 machined screws, which allowed the mounts to be adjustable on the same axis as the drill.
2.21 Trouble Shooting

Because the drill mount did not require manufacture with high strength material, we were able to print the mount using the MackerBot 3th generation 3D printer on campus at JPL. However due to the overhang of the design, the initial prints were unsuccessful.

After rotating the parts to be printing vertically, we were able to successfully print the drill mounts.

3 Results

The designs of the flow cell and drill mount were both successful, and met all of their respective requirements. The dimensions of the flow cell and drill mount are diagramed in figures 10 and figures 11 respectively. We were able to test both the flow cell and drill mount by manufacturing prototypes using a MakerBot 3th generation 3D-printer, using polylactide plastic (PLA) filament.

The flow cell is currently being manufactured (for use at SURF) by Soilid Concepts Inc. using the 3D-printing, selective laser sintering (SLS) process, and will be made with NyTek 1200 PA. The drill mount prototype, made with PLA, had sufficient strength qualities and was therefore used in actual experimentation.
Acknowledgements

I would like to acknowledge the following people for their help and cooperation with the research done.

Prof. Paul McCudden (LACC-CURE director), Prof. Dean Arvidson (LACC), Dr. Rohit Bhartia (JPL mentor), Dr. Greg Wanger (JPL mentor), Dr. Bill Abbey (JPL mentor). Research was conducted at the Jet Propulsion Laboratory, in conjunction with Sanford Underground Research Facility. This work was supported by National Science Foundation grant #AST-1156756 to Los Angeles City College.

Figure: 10
Figure: 11