Pressure Vessel Design for the Testing of MEMS Sensors in a Geothermal Environment

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Introduction

Enhanced Geothermal Systems

- Enhanced Geothermal Systems (EGS) is an energy technology that harnesses the heat of the earth. Impermeable rock kilometers below the surface of the earth is fractured creating a network of fractures through which water may flow. Water is pumped down into the system of fractures where it picks up the earth’s heat. It then returns to the surface of the earth where the heat is converted to electrical energy.
- EGS is a renewable and steady source of Energy with very low emissions.
- An MIT study estimates the amount of extractable heat in the US to “exceed 200,000 EJ or about 2,000 times the annual consumption of primary energy in the United States in 2005.” [1]
- EGS energy production would benefit from improvements in well monitoring technology.

Harsh Environment MEMS Sensors

- A Microelectromechanical systems (MEMS) chip is a micro scale device that combines electrical and mechanical physics to make sensors and actuators.
- Harsh Environment MEMS sensors currently in development at UC Berkeley will be used for down-hole monitoring of Enhanced Geothermal Systems to sense things such as temperature, pressure, and pH. Materials being explored for use in the fabrication of harsh environment MEMS chips include silicon carbide, sapphire, and synthetic diamond. These materials can withstand high temperature and pressure, and resist corrosion when in contact with corrosive media.

Project Overview

In order for new sensors to safely be tested in the lab a geothermal environment must be simulated using a pressure vessel. The aim of this project is to develop a pressure vessel for the safe testing of MEMS sensor robustness and functionality in a geothermal environment.

Parameters

- Must operate safely at up to 30 MPa of pressure and temperatures of up to 400°C
- The inside of the vessel must be made of or coated with chemically inert materials that will not react with the geothermal brine
- The chip needs to be stabilized within the vessel
- Any wiring (including wire-bonding on the circumferential area of the surface of the MEMS chip) must be isolated from the geothermal environment, wires are etched through center of chip
- EGS energy production would benefit from improvements in well monitoring technology

Pencil-and-Paper Sketches

(above) Pros: axial loading, easy assembly
Cons: Screws exposed to geothermal environment, wires are etched through center of chip

(left and right) Pros: axial loading, wire bonding
Cons: complex thrust bearing assembly, there is a problem with the seal, difficult to fabricate, large

Solidworks (Auto-CAD)

- seaside welded into cap body
- nuts and bolts will clamp tool and bottom cap pieces, compressing rubber safety gasket (not shown) and engaging the seal
- with pressure between cap, o-ring, and chip
- cap will be held tightly together with nuts and bolts (not shown)
- Here the cap is inserted into cylindrical pressure vessel, on the other end a cap is screwed over the vessel body

Future Work

- safety analyses of current model
- fabrication of current model
- explore other design ideas that may be easier to fabricate and assemble (see below)
- explore idea of using disposable packaging for chip testing

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Sources