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Abstract

The first quarter of the Downhole Power Generation and Wireless Communications for Intelligent Completions Applications was characterized by the evaluation and determination of the specifications required for the development of the system for permanent applications in wellbores to the optimization of hydrocarbon production. The system will monitor and transmit in real time pressure and temperature information from downhole using the production tubing as the medium for the transmission of the acoustic waves carrying digital information. The most common casing and tubing sizes were determined by interfacing with the major oil companies to obtain information related to their wells. The conceptual design was created for both the wireless gauge section of the tool as well as the power generation module. All hardware for the wireless gauge will be placed in an atmospheric pressure chamber located on the outside of a production tubing with 11.4 centimeter (4 ½ inch) diameter. This mounting technique will reduce cost as well as the diameter and length of the tool and increase the reliability of the system. The power generator will use piezoelectric wafers to generate electricity based on the flow of hydrocarbons through an area in the wellbore where the tool will be deployed. The goal of the project is to create 1 Watt of power continuously.

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List of Graphical Materials

There has not been any graphical material included in this report.

Introduction

The Downhole Power Generation and Wireless Communications for Intellligent Completions Application project was started during this report period. The goals for this period were to determine the specifications and best design approaches for the system. The main areas that were evaluated during this report period were:

- Research the most commonly used casing and tubing sizes for deep gas well production.
- Research the potential for use of molded magnetostrictive technology from UCLA for the generation of the acoustic transmission signals through the pipe.
- Determine the availability of high temperature, high-energy batteries that can be manufactured in a doughnut shape for mounting on the outside of the production tubing.
- Evaluate possible approaches to gather the energies available inside a wellbore and transfer it into the tool for conversion into electricity that can be stored by devices such as super capacitors.
- Evaluate the requirements for the development of a system that will operate at 15,000 ft. Evaluate the requirements to pass the acoustic signal through the tubing hanger and wellhead.
- Evaluate the surface system to operate wirelessly from the wellhead to the doghouse where the processing panel and computer will be located.
- Start the design of the two power generator modules using piezoelectric assemblies and magnets.
- Start the design of the tool mandrel.
- Start the design of the electronics modules for downhole data acquisition and processing.

Executive Summary

The highlights of the accomplishments for this report period are listed below.

1. The evaluation of the casing and tubing sizes most often used in deep gas well was performed. Amerada Hess, BP, Anadarko, Shell and ExxonMobil were contacted about that issue. The common casing diameters are 7 5/8 inches and 9 5/8 inches with 53lbs weight. The tubing sizes preferences varied from 4 ½ to 7 5⁄8 inches including multiple tubing weights. The final tubing size was determined during a second round of questions to the producing companies. The standard casing size that will be used for the wireless tool is 7 ½ inches OD and the tubing size is 4 ½ inch OD. The new wireless tool will be developed with thread connection sizes for 4½ inch production tubing. The tool ID will be 3 ½ inches while the OD will be 5 ¾ inches.
2. Professor Carman at UCLA was contacted concerning his research work on molded magnetostrictive material for acoustic generation. A company called Fortis located in Los Angeles has commercialized the magnetostrictive technology. Dr. Wade Pulliam is in charge of the material program and he has indicated that it is possible to utilize the magnetostrictive material for high temperature applications inside wellbores. The ability of manufacturing of a magnetostrictive assembly has not been verified although a piezoelectric wafer assembly can be manufactured to our specifications. A new tooling system will have to be created to build the piezo assembly.
3. A new battery company has developed a high-energy battery that can be manufactured in a doughnut shape for mounting outside the tubing. This battery can be used for the new system to provide auxiliary energy inside the wellbore. The battery operates at 150 degrees Celsius and has been used by Schlumberger in some of its applications. A company called Southwest Energy in Houston has build battery packs that include the doughnut shaped battery cells.
4. The main sources of energy in the wellbore include flow, vibration, pressure and noise. The purpose of this task is to evaluate the energies available and how to obtain it and transfer the energy into the tool for processing and storage. The main goal is to use a non-movable or sealed hardware approach to gather energy. Two approaches have been selected as the most promising techniques to gather the well energy. The first approach uses the force generated by the flow into the tool walls to convert mechanical motion into electrical energy. The system will have a force amplifier module that will interface to a piezoelectric assembly. The amplifier will compress and release the piezo assembly to generate the electricity. An electronics based power conditioning module will convert the AC signal into a DC signal for storage into supercapacitors. The second approach will use a module mounted in the inner wall of the tool.

The module will have grooves that will cause it to rotate as the well flow goes by the grooves. The module will have rare Earth permanent magnets imbedded in the assembly that will rotate with the module rotating the magnetic field. The tool walls will be wound with transformer wires that will create a voltage as the magnet fields change inside the coils.

5. The existing surface system for downhole wireless gauges can be modified to operate in conjunction with a low power wireless communications using existing commercial boards that have been developed for use in PC communications. The board will be installed in the surface acoustic to electrical pulses converter and in the surface processing panel for two way communications.
6. Two tool designs were evaluated during this report period. The first design uses a side pocket concept where the electronics is placed inside the mandrel in an opening to the outside of the tubing for loading the electronics hardware into the tool. The second design uses the outside of the tubing to mount all hardware require by the system. A pressure housing would be screwed onto the tubing outside diameter to seal the electronics and other hardware into an atmospheric chamber. The second approach was chosen for the development of this tool due to the shorter tool length and larger area for mounting of the components.
7. The design work related to the downhole power generator has started. A piezoelectric assembly required for the evaluation of the amount of power that can be generated downhole has been received and tested. A formula for power versus force on the piezo assembly has been verified and will be used in the design of the piston. A new approach for the magnetic based system for power generation has been created where the rotation of the assembly is independent of the erosion and seals.
8. The design of the mandrel has been started and the main focus is the requirements for 15,000 psi pressure rating. An evaluation of the wall thickness and material requirements was made.
9. The surface system design issues were addressed during this report period.
    a. The ability to communicate wirelessly between the acoustic to electrical converter located at the wellhead and the surface processing panel was addressed and it was decided that a wireless system will be used causing the converter module design to include rechargeable batteries for independent operation as well as for well safety since no electricity will be required around the wellhead.
    b. Another issue addressed related to the Personal Computer versus Palm Handheld Computers. We will attempt to design the new system so that it can be operated using a handheld computer.
    c. The overall specifications for the surface system were finalized.
10. The surface to downhole communication was also addressed during this report period with two significant issues identified as critical to the design of the downlink module: Diameter and power.

Experimental

Experimental Apparatus –The experimental apparatus for this project will be developed during the next quarter. The only apparatus used for experiment was the development and manufacturing of a power generator assembly using piezoelectric wafers. The wafers were compressed using a "C' clamp. An electronic circuit composed of a resistor and an oscilloscope were used to measure the voltage and current generated by the piezo assembly as it was compressed and released.

Experimental and Operating Data - The approximate Voltage output at compressive force/movement is calculated as following:

Mo = g33*t
Mo = 0.025 V-m/N * 0.000508 meters (t = 0.020 inches)
Mo = 1.27EE-5 V-m**2/N
Mo = 1.27EE-5 V/Pa
Mo = 1.27EE-5 V/(0.000145 psi)
Mo = 0.08759 V/psi (Output = Electrical Voltage[V] per Mechanical Stress [psi])

Max compressive force that can be applied to the stack should not exceed 4500 psi under any conditions. A linear reduction in output sensitivity with increasing pressure (about a 5-10% loss per 1000 psi above the 4500 psi level) can be expected. Force = 4500 psi * 0.7854 in**2 = 3,534.3 pounds for a stack with an "active" diameter equal to 1.00 inches.

Also, one should be careful with your cable capacitance. There are stray capacitance losses when the sensor (output) needs to drive long cable lengths. Let's assume the stack capacitance (Cs) equals 750 nF and you are driving an output signal 10 feet through cable with a capacitance value of 100 pF/ft for a total Cc value of 100*10 = 1.0 nF. Your sensitivity reduction would be

Mo(new) = Mo*((Cs / (Cs + Cc))) = Mo*((750/(750 +1)))= 99.87%Mo

It turns out our stack uses many layers connected in Parallel (electrically) and in Series (mechanically). This holds your sensitivity constant, but provides high capacitance which helps to reduce the influence of cable losses.

Results and Discussion

The results indicate that the system can be developed using 4½ inch tubing. The tool will utilize standard threads used in high temperature, high pressure wells applications. The tool design will incorporate electro-acoustic components located on the outside of the production tubing and the components will be housed in a pressure chamber attached to the Outside Diameter of the tubing via threads.

Standard material will also be used to build the tool. The system will be able to withstand 15,000 psi by using 4140 material with a P-120 strength. The two-way communications will be performed through the production tubing using piezoelectric wafers or magnetostrictive material for acoustic signal generation.

A concept was created to transfer data from the wellhead to the surface data acquisition and process panel wirelessly. The use of commercial short hop electromagnetic waves to transfer data will be used.

The power generation preliminary tests indicated that the compression of the piezoelectric wafers mounted on a stack setup format generated electricity that can be harvested and stored inside the downhole tool to power the electro-acoustic system.

The development of the drawings required to manufacture the downhole power generator will be created during the next report period. The mechanical design of the wireless gauge will also be developed during the next quarter.

All goals for the project for this quarter were met.

Conclusion

The conclusions for the first quarter for this project are as following:

- The wireless communications tool can be developed using piezoelectric wafers that will fit within the tool ID and OD. The tool mechanical design will occur during the next report period based on the information obtained from the potential customers on diameters of tubing and casing and pressure and temperature requirements.
- The module used for testing the concept of power generation using piezoelectric ceramic material indicated that a small module can generate up to 100 milliWatts and that multiple assemblies can be placed in parallel to generate the required 1 Watt of power downhole continuously. The mechanical design for the power generator will occur during the next report period. The piezoelectric wafers will be placed on the tubing wall to sense changes in pressure and flow to generate the power required to operate the downhole tool. The electronics modules attached to the power generator modules will be placed in parallel inside the tool to provide the energy required to operate the downhole gauge.
- The new wireless tool will be developed with thread connection sizes for 4½ inch production tubing. The tool ID will be 3 ½ inches while the OD will be 5 ¾ inches. This conclusion was based on requirements from the major and independent hydrocarbon producers.
- The wireless tool design will use the outside of the tubing to mount all hardware require by the system. A pressure housing will be screwed onto the tubing outside diameter to seal the electronics and other hardware into an atmospheric chamber. This approach was chosen for the development of this tool due to the shorter tool length and larger area for the mounting of the components compared to a design where the electronics would be placed inside tubes located on the outside of the pipe.
- The project is on schedule following the completion of the first quarter of development. The basic research provided on the system size and power generation ability shows that the system can be developed successfully.
- The system development is on schedule.

References

There are no references related to this project and work performed over the past 3 months.

Bibliography

There is no bibliography related to the work being performed.

List of Acronyms and Abbreviations

There are no acronyms or abbreviations in this report.