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Thermodynamics of Compact Downhole Turbo Generators

V. John Fernandez, Novatek, Parthasarathi Ghosh, Indian Institute of Technology, Kharagpur, Darryl James, Texas Tech University

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Abstract

A turbine assembly for downhole use is being developed for use in drill pipe and annular locations in the well that require small power generation devices. Such devices are required in high speed data transmission drilling strings currently being introduced in the industry. Discrete array of sensor banks mounted on the wired drill string require a local power source that directs electric energy to tools located in a particular sensed section of the well being drilled.

The thermodynamics of the compact generators is typically cryocooling with reverse Brayton cycle expansion, liquefying in bulk gases such as helium. The high efficiency compared to membrane separation makes this method of helium distillation suitable for diverse uses such as NMR equipment and superconducting conductors.

This paper details the thermodynamics of a high-efficiency cycle power generation system for such drill strings the development of components in the system used to arrive at the target efficiency levels defined by the generation cycle. The lessons learnt from the cryogenic compact turboexpanders, which include mixed radial inlets and axial discharge configurations are illustrated in the development of this turbine generator for downhole drilling use. Additionally, supercomputer simulations on structural and fluid mechanics conditions downhole are used to understand, in detail, the system and component level thermodynamics of the turbo-generator.

The conclusions of this thermodynamic cycle development work is that a small profile, side-mounted power source can be developed for use in drilling applications, particularly where the center bore of the drill string is required to be a clear pathway. The small profile of this solution enables completion strings used in intelligent fields to be powered, in addition, where the side-mounted power source is readily integrated into small cross-sections.

Introduction

Power sources in downhole drill normally consist of long battery packs or turbine power sections which take long lengths in the tool strings. The power budgets for the battery sections are estimated based on the expected duration of a section of the well to be drilled. Typical turbine power sections consist of center-axis-concentric turbine blades, converting mechanical work from mud to electrical power. The power output from such sections is routed to adjacent data gathering tools. The location of such tools is fixed relative to the power sections. Such arrangements limit the placement of additional data gathering locations in the tool string without the addition of long power sections.

New drill strings consisting of pipe sections hardwired for data and power. For such pipe, placing data gathering devices for information such as formation fluid sampling will be comparatively less massive with the addition of a compact power source. This small profile power source will also enable other technologies for instantaneous sampling and or measurement and drill string control. All these features will ensure accurate and optimal placement of the borehole next to the hydrocarbon bearing formation. Wireless solutions can also benefit from such a device by providing a place for signal boost along with reservoir and drill string measurements. The technology can additionally be utilized in the completion phase of the well, for providing power to stand-alone wireless completions providing data on the well producing/injecting phase as well as field conditions in general.