This paper explores the application of the ViscoRotary Engine Power System (VREPS), a novel micro power generator based on surface shearing stresses, in several thermodynamic cycles. The thermal efficiencies and operating characteristics of each configuration will be presented. VREPS consists of four major components: a viscous turbine, nickel-iron magnetic circuits electroplated into an etched silicon wafer, an external permanent magnet, and an externally mounted electric generator. All of these components are integrated into a singular modular package, as shown in Figure 1. The viscous turbine is modeled after the macro-scale drum and cylinder viscometer; however, the flow is driven by an external pressure gradient instead of by the rotation of the inner cylinder. Thus, the resulting flow field in the gap is a Couette-Poiseuille flow. The mechanical power generated by the shearing forces at the wall of the rotating cylinder is used to create an oscillating magnetic field by switching the steady magnetic field emanating from the external permanent magnet between two paths (a) and (b) as shown in Figure 1. Magnetic field switching is accomplished as magnetic-material poles embedded in the viscous turbine rotor alternate position. Next, the oscillating magnetic field is passes through the electric generator by way of the magnetic circuits and is converted into electricity. The magnetic circuits and the external generator are currently under development by D G Jones and M Senesky, respectively [1,2].

Micro power generation has attracted the attention of numerous researchers over the last decade. Many of their projects have sought to miniaturize existing macro-scale devices, while a few have examined unique solutions to power generation at small length scales. For example, the micro Wankel engine at UC Berkeley and the micro gas turbine at MIT were designed to harness inertial forces in the same way as their macro-scale counterparts [3, 4]. Unfortunately, surface viscous shearing forces and inertial forces do not scale uniformly as length scales decrease; rather, the shearing forces become much more significant at small length scales [5]. Therefore, a micro power generation device that relies on surface viscous shearing forces may be able to overcome efficiency limitations endemic to current micro-scale power generators which use inertial forces to generate mechanical power. The concept of a viscous dominated power generator is not new; the Tesla Turbine, patented by Nikola Tesla in 1913, relies on a viscous dominated flow to transfer energy [6]. VREPS is similar in this regard because it uses surface shearing forces to extract mechanical power from the working fluid.

A static analysis of VREPS has been presented using a Creeping Flow model and a numerical optimization of the device’s isentropic efficiency; however, thermal efficiencies of thermodynamic cycles involving VREPS have not been reported [7]. Cauley, Rosario, and Pisano proposed a design that consists of a 250 µm thick, 3.4 mm OD / 2.4 mm ID annular rotor with embedded magnetic poles and four 10 µm driving channels on each side of the rotor. They reported an isentropic efficiency of 25% and a power output of 825 mW using a pressure drop of 5MPa across the device. The isentropic efficiency and power output for this device are provided in Figure 3 [7].
Figures

![Overall Schematic of the VREPS](image)

**Figure 1:** Overall Schematic of the VREPS

![Schematic of a disk viscous turbine with (A) the flow in the seal and (B) the flow in the driving channel](image)

**Figure 2:** Schematic of a disk viscous turbine with (A) the flow in the seal and (B) the flow in the driving channel

![Performance plot for optimized annular viscous turbines for a pressure drop of 5 Mpa](image)

**Figure 3:** Performance plot for optimized annular viscous turbines for a pressure drop of 5 Mpa

References


