Solar Smoleniec/Stirling Hybrid Thermo-Mechanical Generator

Some Analytic Performance Results

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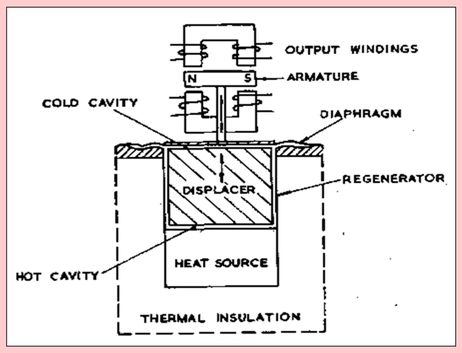
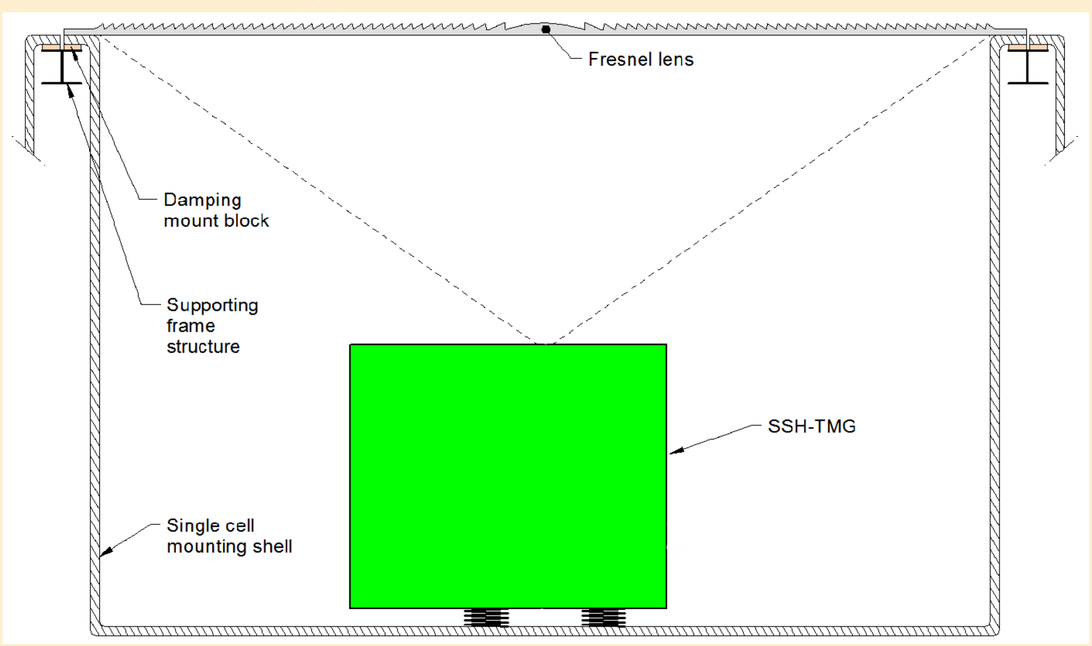
The Thermo-Mechanical Generator was invented by E.H. Cooke-Yarborough in 1967 and is an ingeniously simple and elegant heat engine operating on a Stirling thermodynamic cycle. Mechanically, the engine operates as a Free Displacer Stirling Engine with the normally solid piston replaced with a diaphragm that oscillates at high frequency (50-140 Hz) with a small amplitude (1-5 mm).



Classical Thermo-Mechanical Generator (Cooke-Yarborough, 1975)

A new version of this heat engine has been invented by the Principal Investigator that is capable of operating off concentrated solar energy provided by inexpensive, acrylic Fresnel lenses. A key innovation in the technology is the use of a digital thermodynamic Smoleniec/Stirling cycle to optimize the performance of the heat engine in real time. The Solar Smoleniec/Stirling Hybrid Thermo-Mechanical Generator (SSH-TMG) co-generates alternating current electricity and thermal energy.



SSH-TMG in mounting frame (redacted)

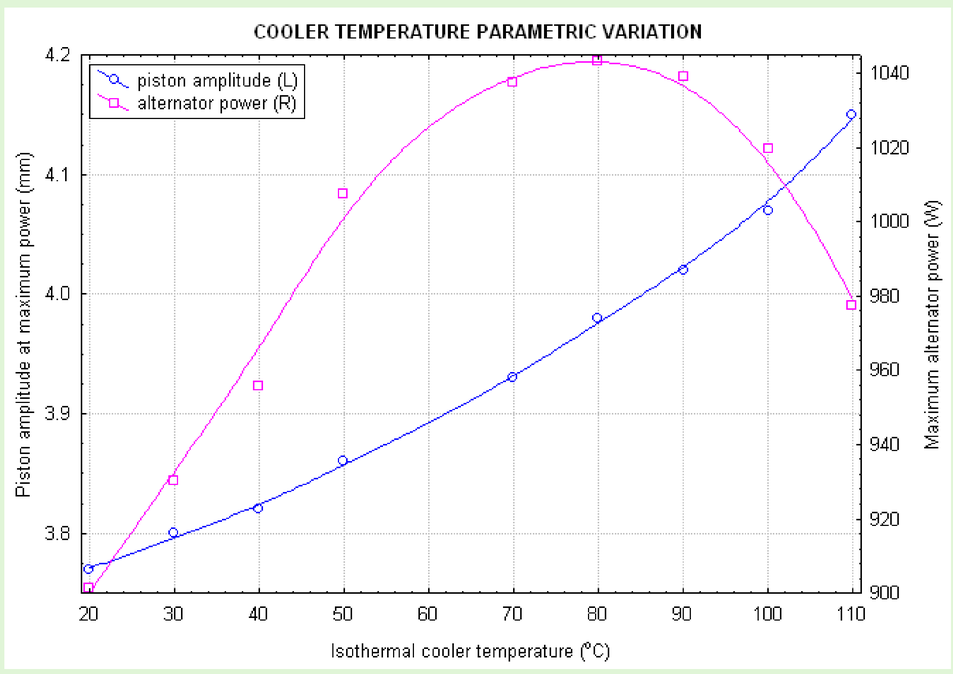
A State Space analysis was developed to design the engine components so that stable engine oscillation can be achieved. The analysis yields an overall "design equation" relating all the salient engine variables that can be expressed as follows:

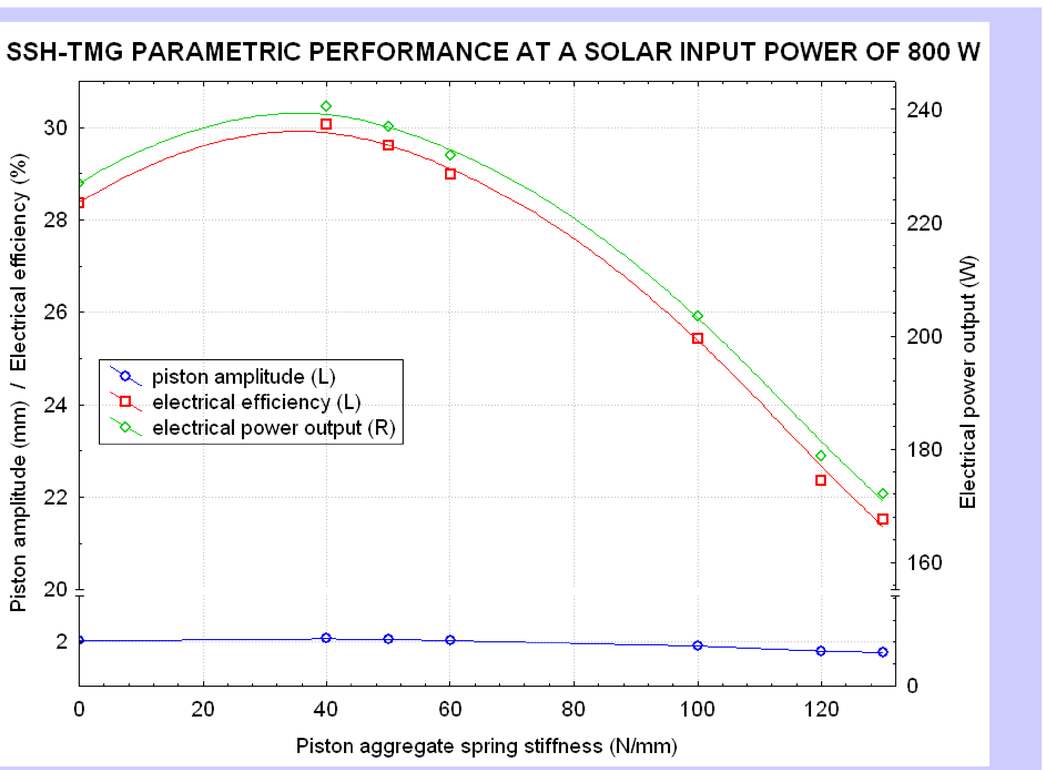
$$B_1^2 + B_3^2 B_0 = B_1 B_2 B_3$$

where B_i are composite constants.

Solution of this equation allows the engine performance to be optimized in terms of maximizing the electrical power output as a function of all the design variables embedded in the equation.

Isothermally varying the cooler temperature shows a maximum power output of 1040 W corresponding to a piston amplitude of 4.19mm at a cooler temperature of 80°C.





A coupled continuum mechanics / dynamics simulation was developed to solve the full set of mass, momentum, energy and entropy transport equations simultaneously with the engine dynamics equations. The purpose of the simulation was to eliminate the simplifying assumptions made in the State Space analysis and determine the likely performance of the SSH-TMG under realistic insolation conditions.

At an input solar power of 800W, the engine yielded a maximum electrical output of 240.5 W for an electrical efficiency of 30%. Note the small piston amplitudes of 2 mm or less.

The SSH-TMG is characterized by an output power curve that is fairly flat as a function of insolation but with a steep decrease in electrical efficiency as the solar power input is increased.

The coupled continuum mechanics / dynamics simulation is in agreement with the State Space analysis within 10%.

The results achieved compare favorably with those of a recently announced high performance commercial photovoltaic panel producing 225 W at a module efficiency of 17.8%.